US011614734B2

(12) **United States Patent**
Bergan et al.

(10) **Patent No.: US 11,614,734 B2**
(45) **Date of Patent: *Mar. 28, 2023**

(54) **LOCAL DRONE IDENTIFICATION VERIFICATION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 174 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **17/193,312**

(22) Filed: **Mar. 5, 2021**

(65) **Prior Publication Data**

US 2021/0208580 A1 Jul. 8, 2021

Related U.S. Application Data

(63) Continuation of application No. 15/844,925, filed on Dec. 18, 2017, now Pat. No. 10,969,777.
(Continued)

(51) **Int. Cl.**

G05D 1/00	(2006.01)
B64C 39/02	(2023.01)
B64D 47/02	(2006.01)
G05D 1/10	(2006.01)
G08G 5/00	(2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***G05D 1/0016*** (2013.01); ***B64C 39/024*** (2013.01); ***B64D 47/02*** (2013.01); ***G05D 1/0022*** (2013.01); ***G05D 1/0027*** (2013.01); ***G05D 1/0033*** (2013.01); ***G05D 1/104*** (2013.01); ***G08G 5/0069*** (2013.01); ***G08G 5/0082*** (2013.01); ***H04W 4/02*** (2013.01); ***H04W 4/90*** (2018.02); *B64U 2201/10* (2023.01); *B64U 2201/20* (2023.01)

(58) **Field of Classification Search**
CPC .. G05D 1/0016; G05D 1/0022; G05D 1/0027; G05D 1/0033; G05D 1/104; B64C 39/024; B64C 2201/141; B64C 2201/146; B64D 47/02; G08G 5/0069; G08G 5/0082; H04W 4/02; H04W 4/90
See application file for complete search history.

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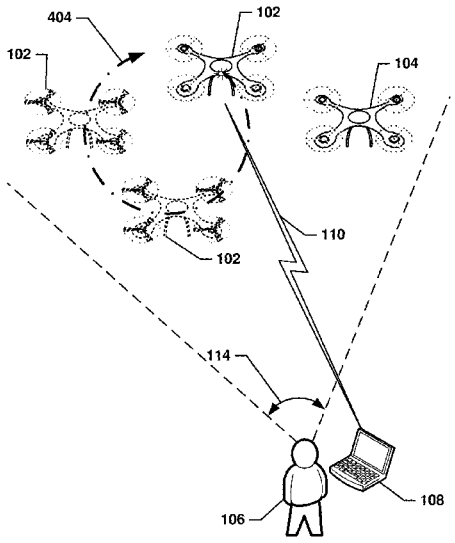
(57) **ABSTRACT**

Systems, methods, and devices of the various embodiments enable local visual identification and verification of robotic vehicles. Various embodiments may enable disambiguation of a robotic vehicle from among a plurality of robotic vehicles.

29 Claims, 19 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/524,312, filed on Jun. 23, 2017.

(51) **Int. Cl.**
H04W 4/02 (2018.01)
H04W 4/90 (2018.01)

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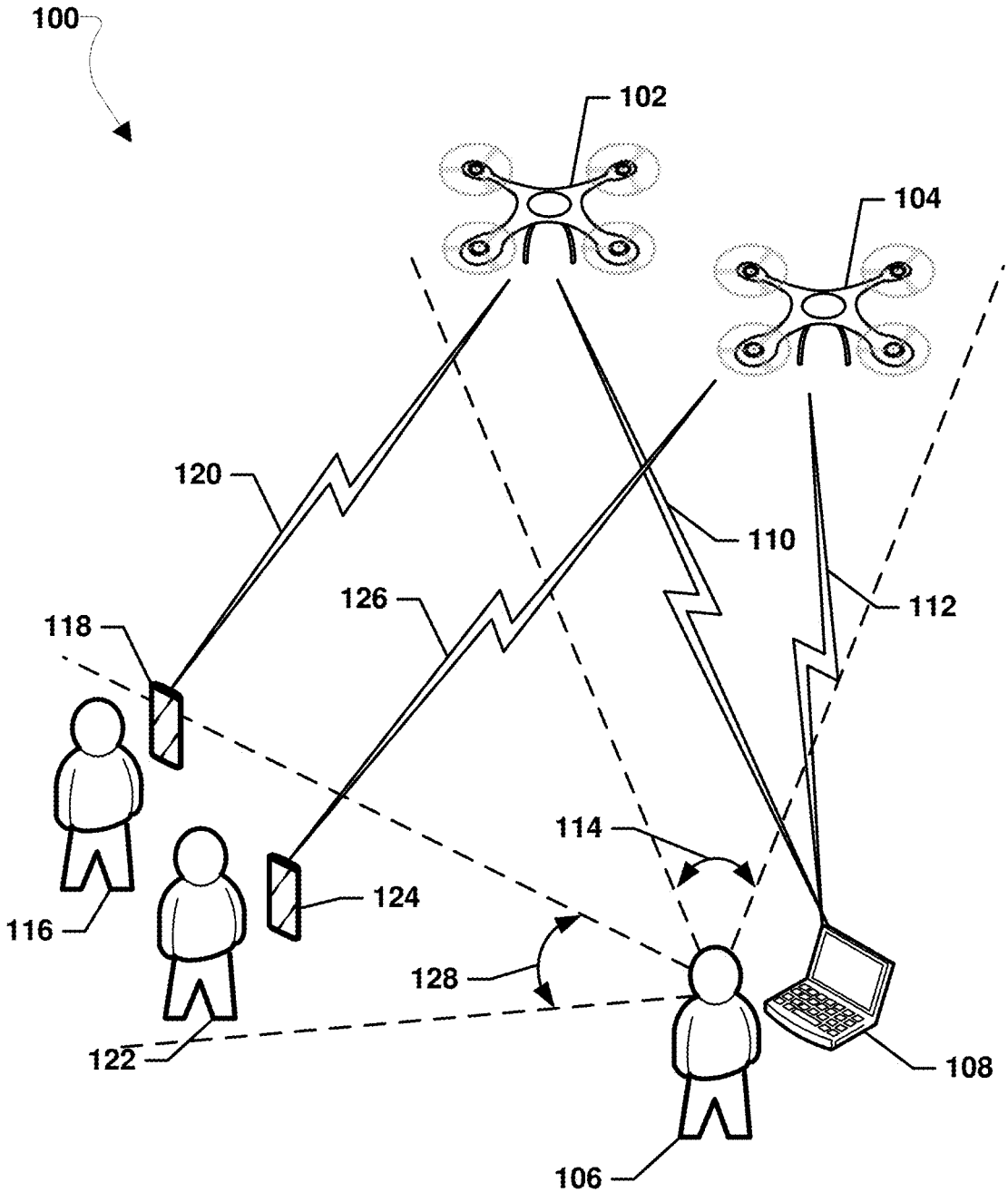

FIG. 1

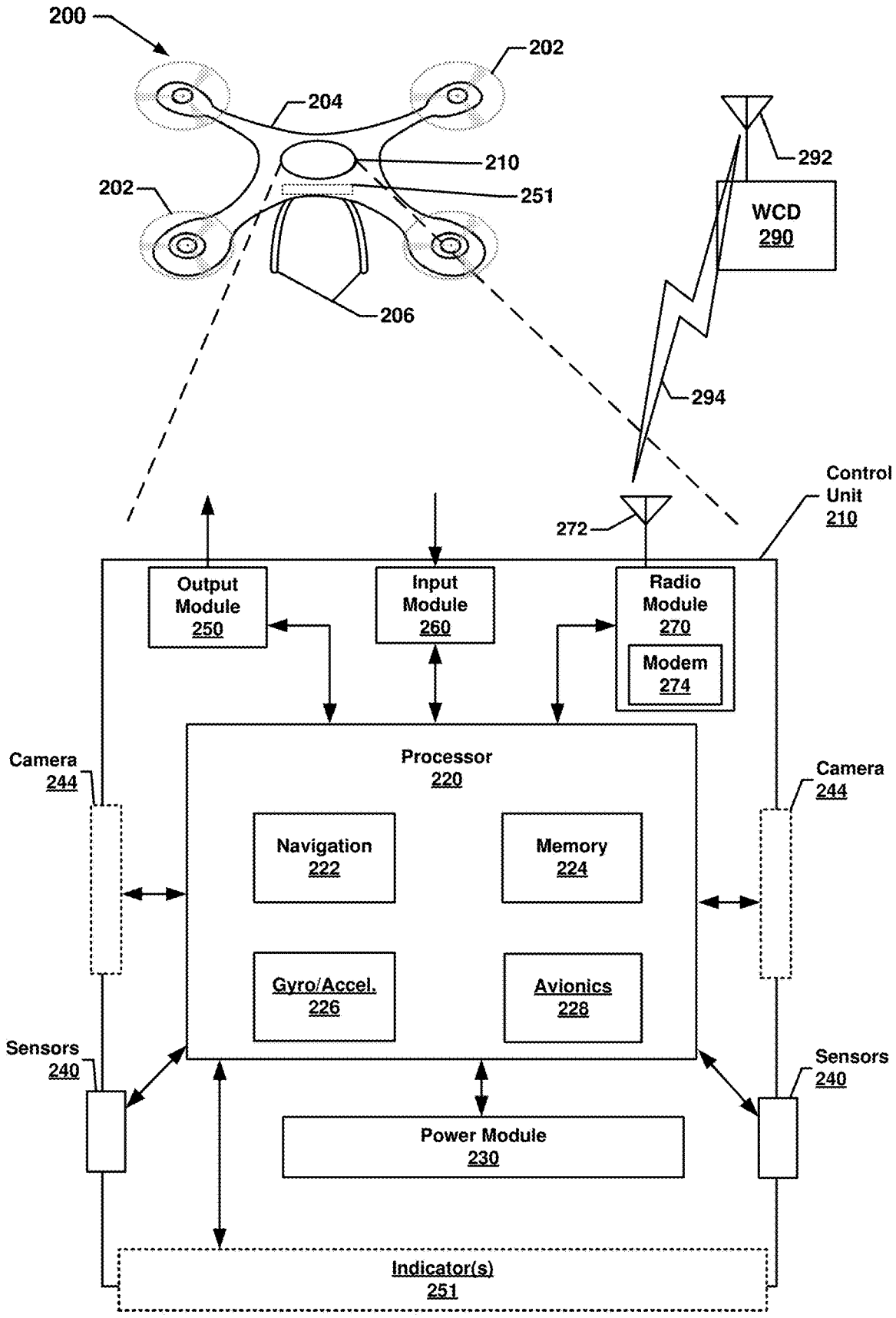
200
202
204
210
251
202
206
292
WCD
290
294
272
Control
Unit
210
Output
Module
250
Input
Module
260
Radio
Module
270
Modem
274
Processor
220
Navigation
222
Memory
224
Gyro/Accel.
226
Avionics
228
Camera
244
Camera
244
Sensors
240
Sensors
240
Power Module
230
Indicator(s)
251

FIG. 2

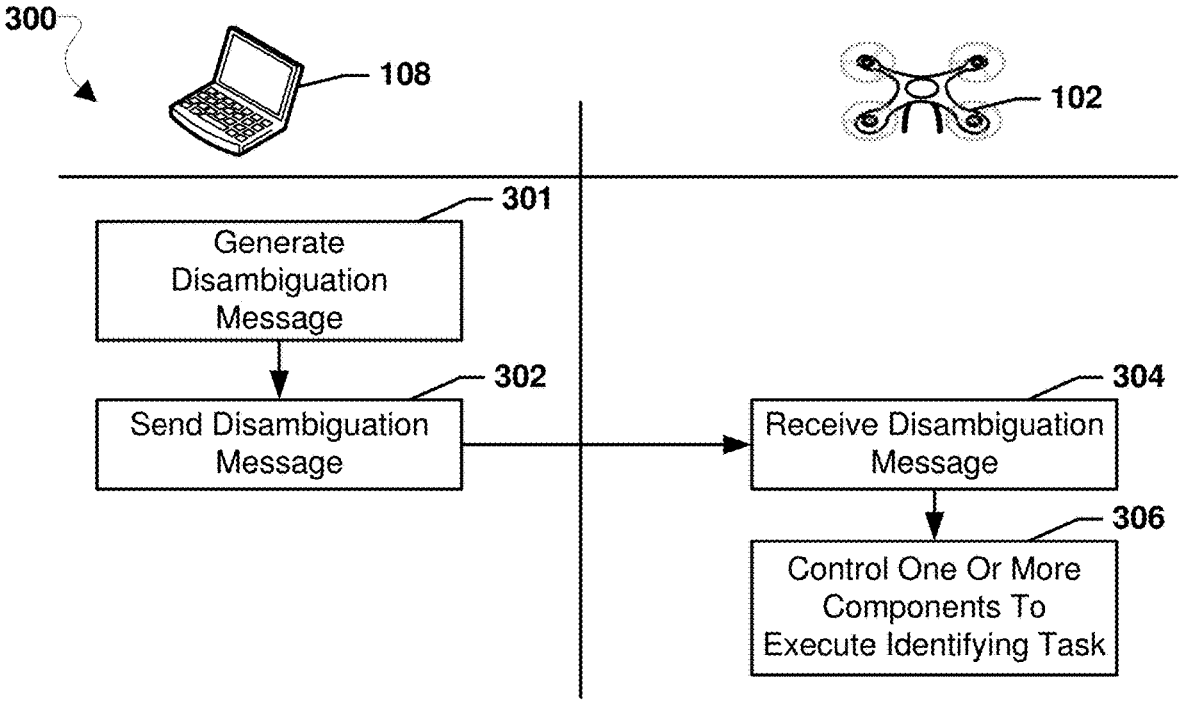
300
108
102
301
Generate Disambiguation Message
302
Send Disambiguation Message
304
Receive Disambiguation Message
306
Control One Or More Components To Execute Identifying Task

FIG. 3A

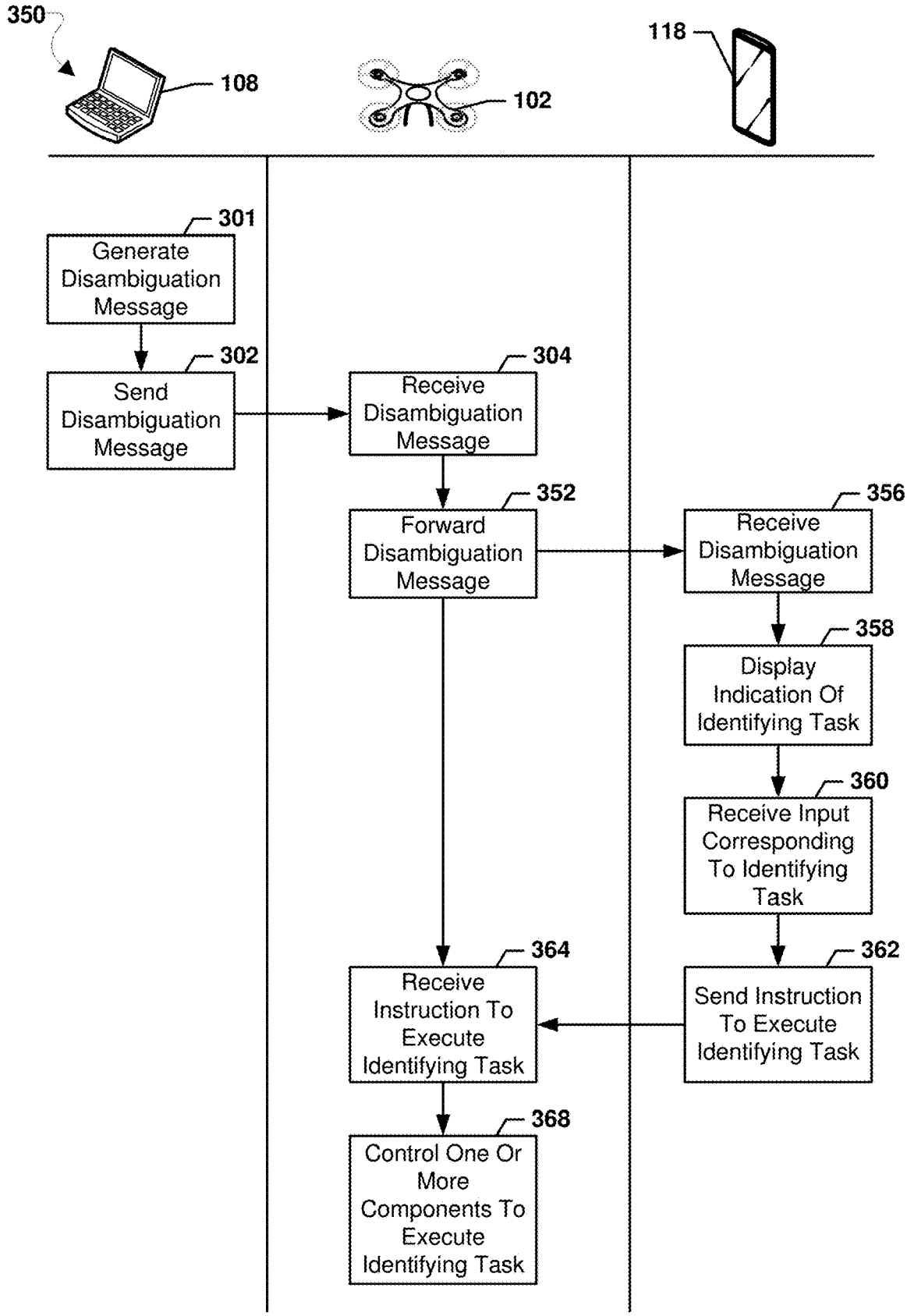
350
108
102
118
301
Generate Disambiguation Message
302
Send Disambiguation Message
304
Receive Disambiguation Message
352
Forward Disambiguation Message
356
Receive Disambiguation Message
358
Display Indication Of Identifying Task
360
Receive Input Corresponding To Identifying Task
362
Send Instruction To Execute Identifying Task
364
Receive Instruction To Execute Identifying Task
368
Control One Or More Components To Execute Identifying Task

FIG. 3B

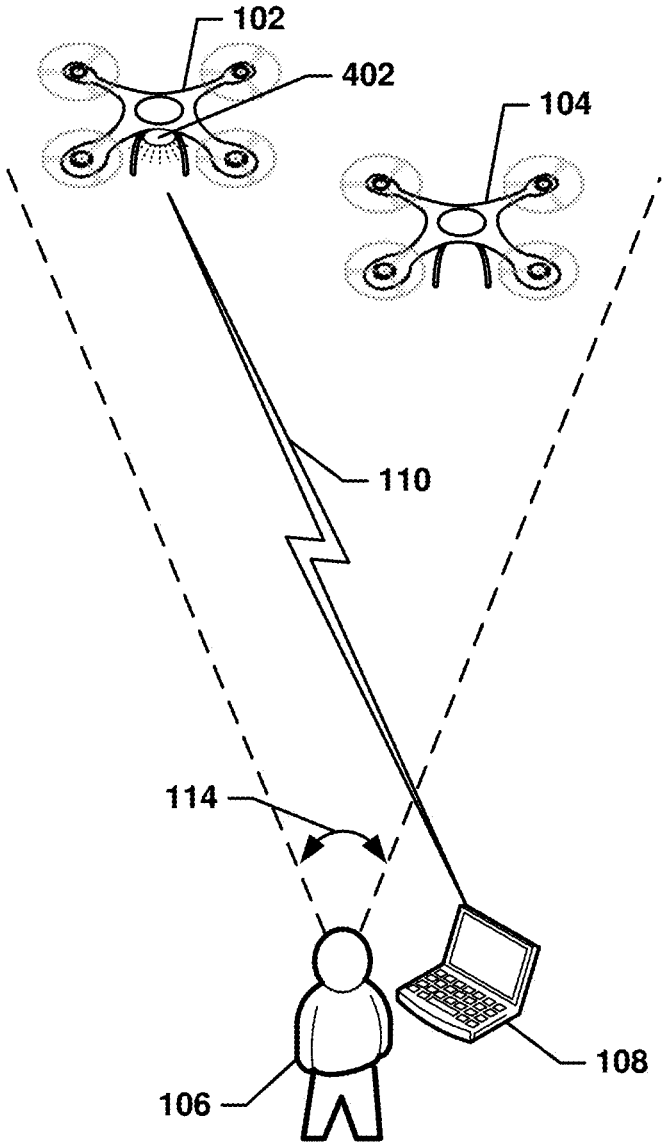

FIG. 4A

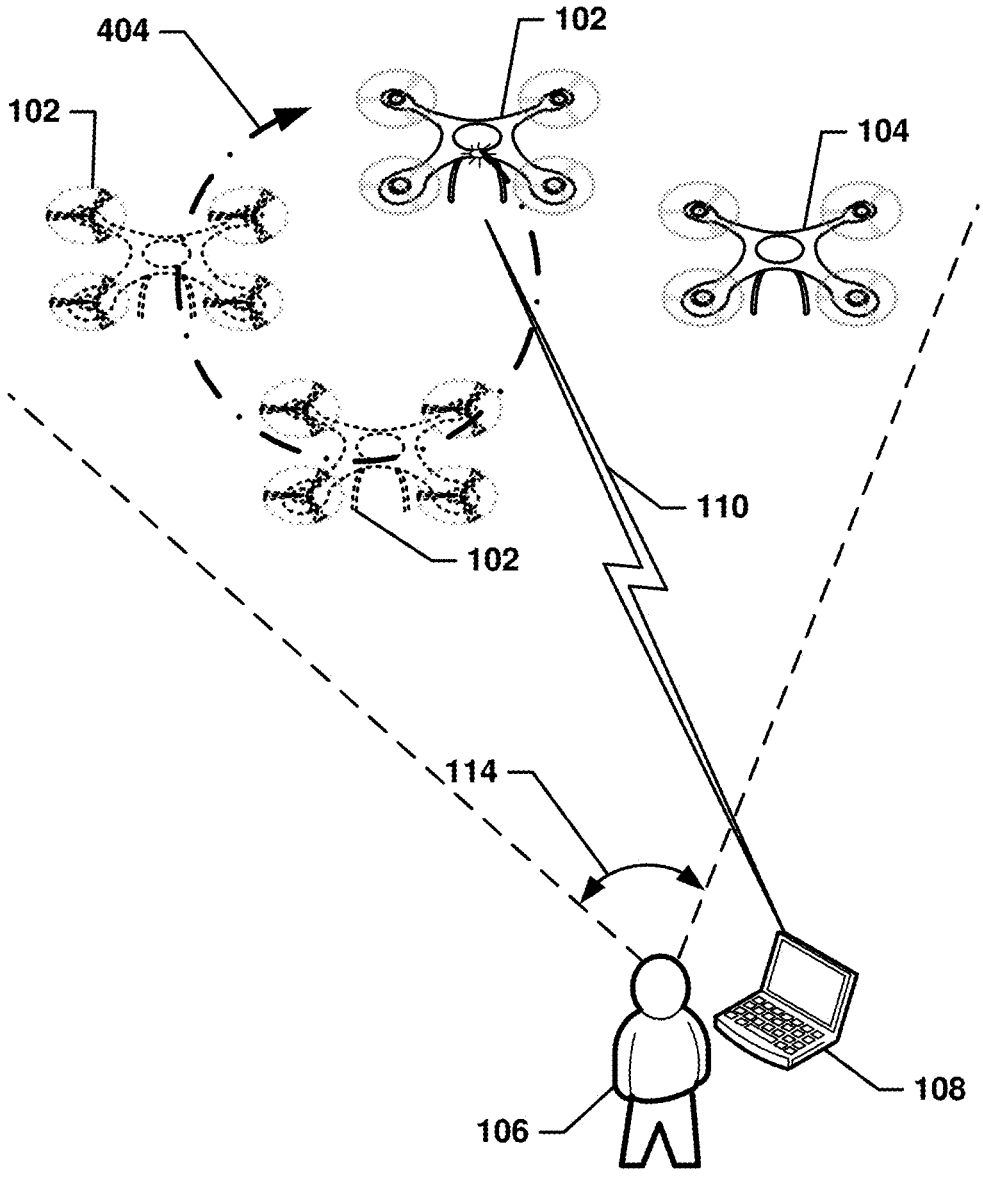

FIG. 4B

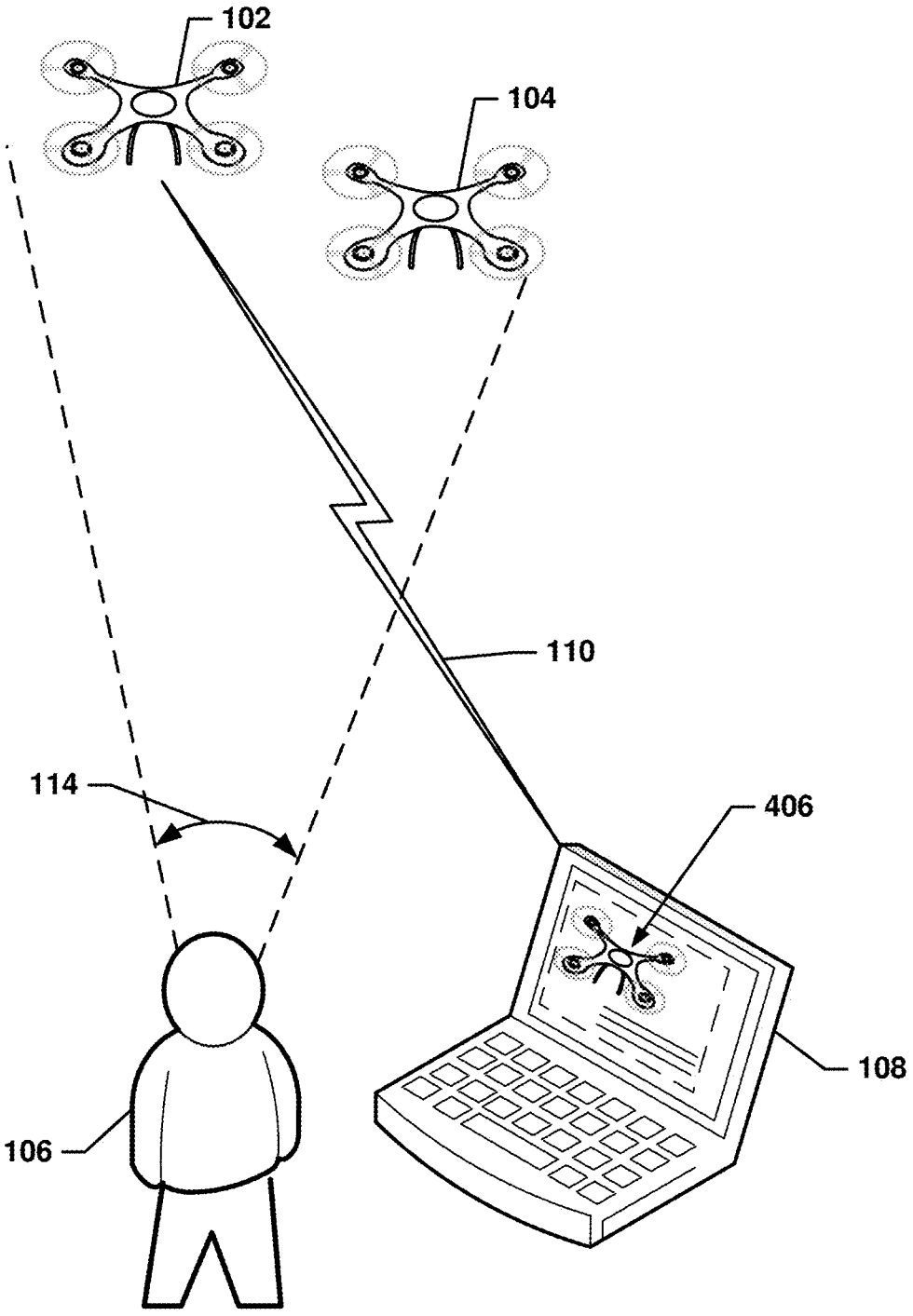

FIG. 4C

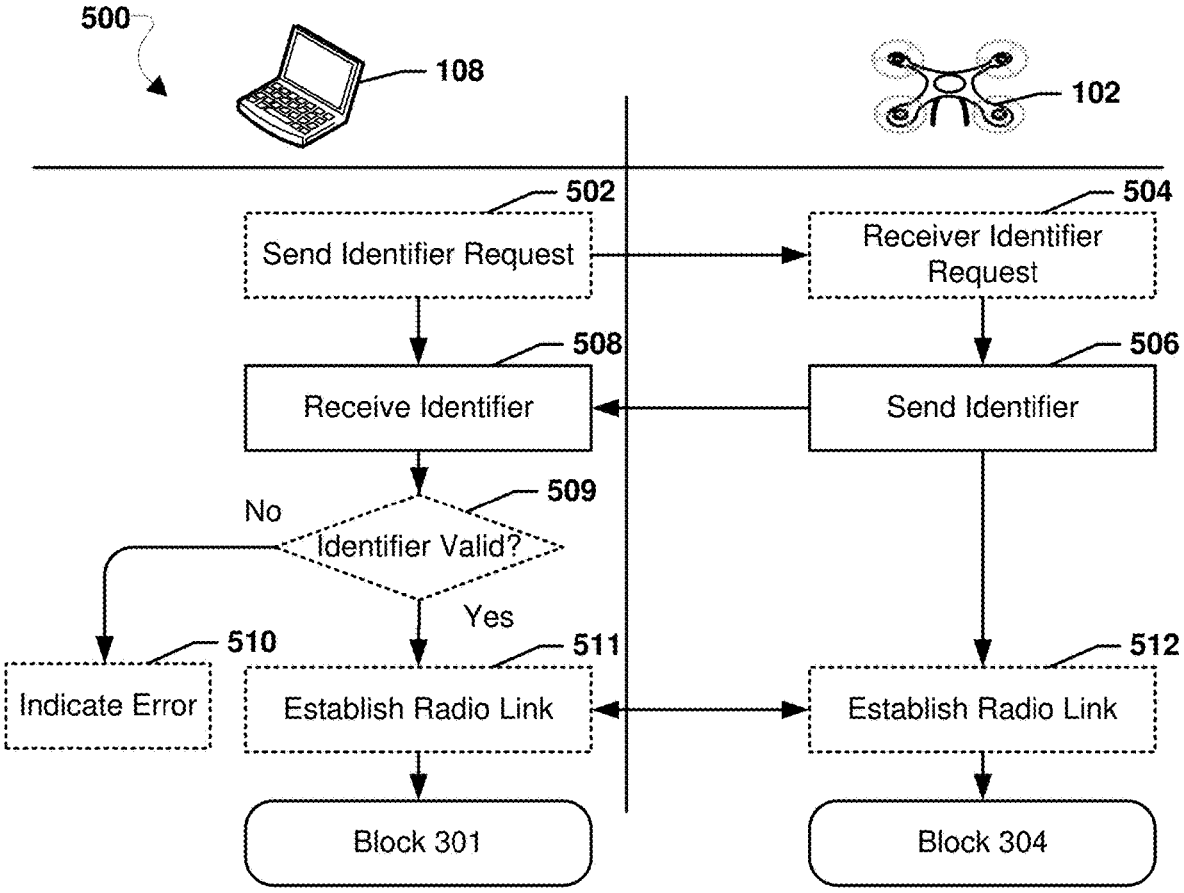
500
108
102
502
Send Identifier Request
504
Receiver Identifier Request
508
Receive Identifier
506
Send Identifier
509
No
Identifier Valid?
Yes
510
Indicate Error
511
Establish Radio Link
512
Establish Radio Link
Block 301
Block 304

FIG. 5

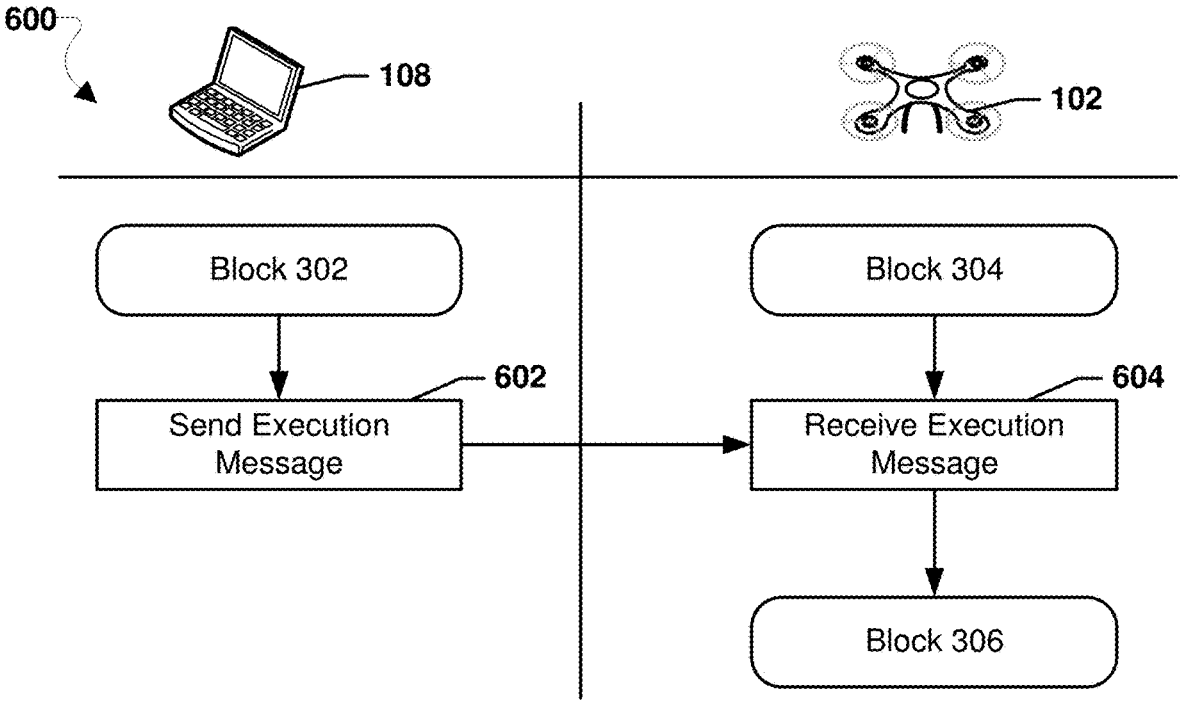
600
108
102
Block 302
Block 304
602
604
Send Execution Message
Receive Execution Message
Block 306

FIG. 6A

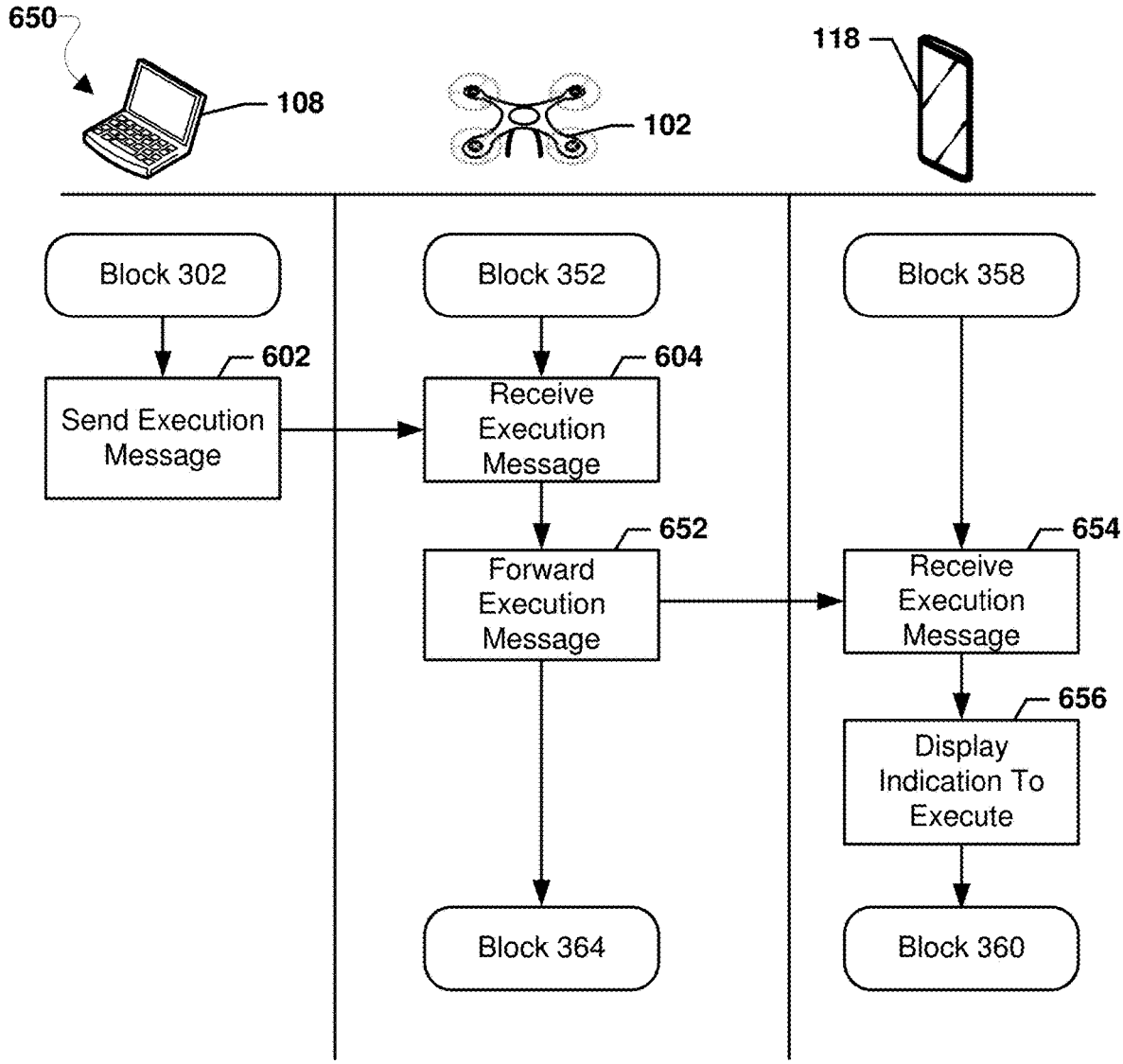
650
108
102
118
Block 302
602
Send Execution Message
Block 352
604
Receive Execution Message
652
Forward Execution Message
Block 364
Block 358
654
Receive Execution Message
656
Display Indication To Execute
Block 360

FIG. 6B

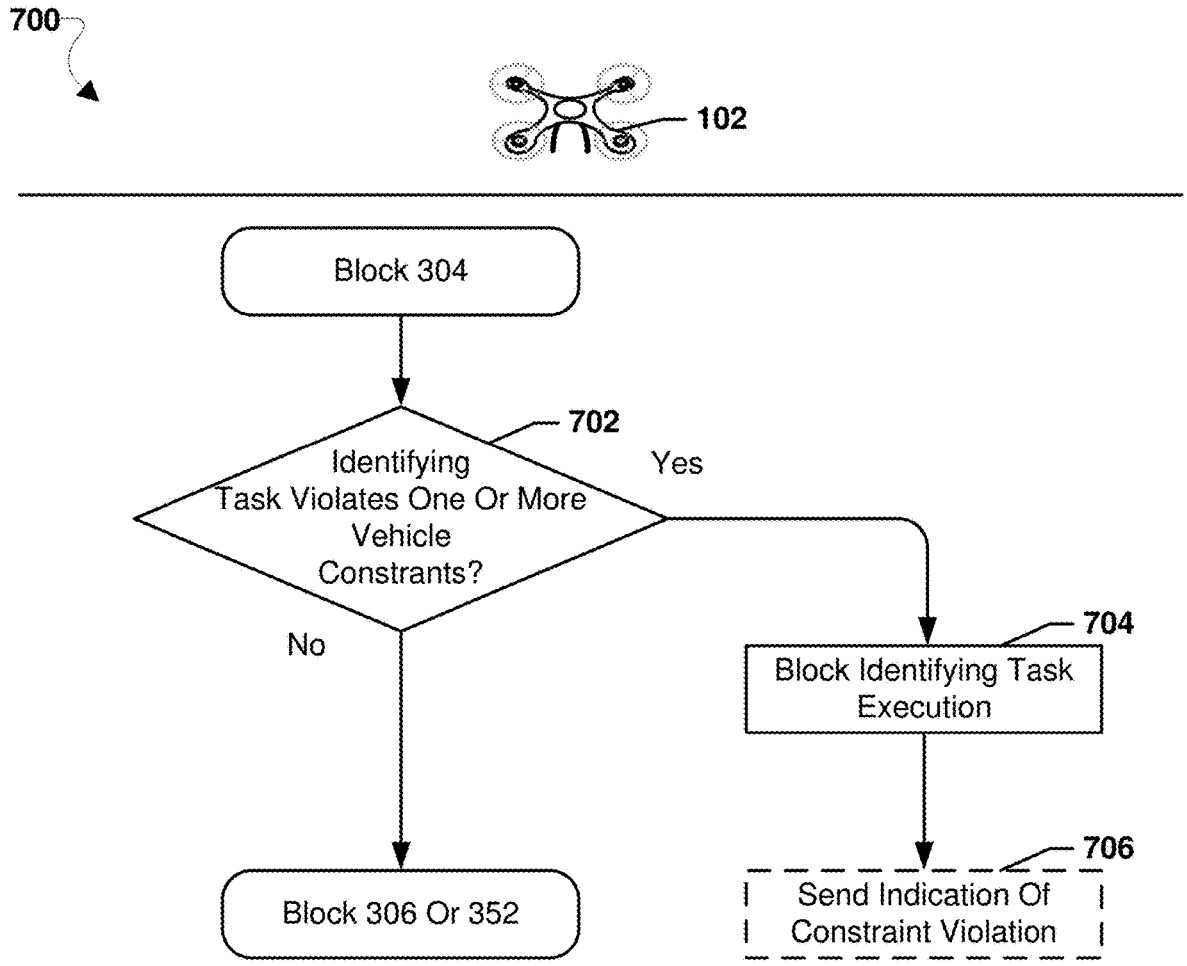
700
102
Block 304
702
Identifying Task Violates One Or More Vehicle Constrants?
Yes
No
704
Block Identifying Task Execution
706
Send Indication Of Constraint Violation
Block 306 Or 352

FIG. 7

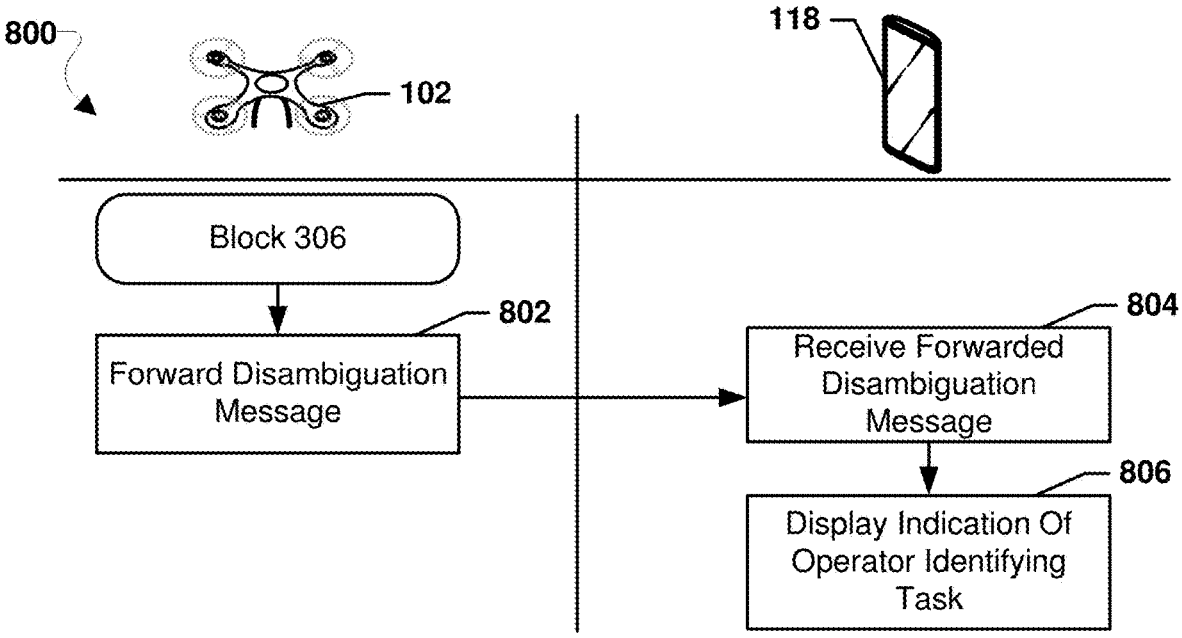
800
102
118
Block 306
802
Forward Disambiguation Message
804
Receive Forwarded Disambiguation Message
806
Display Indication Of Operator Identifying Task

FIG. 8A

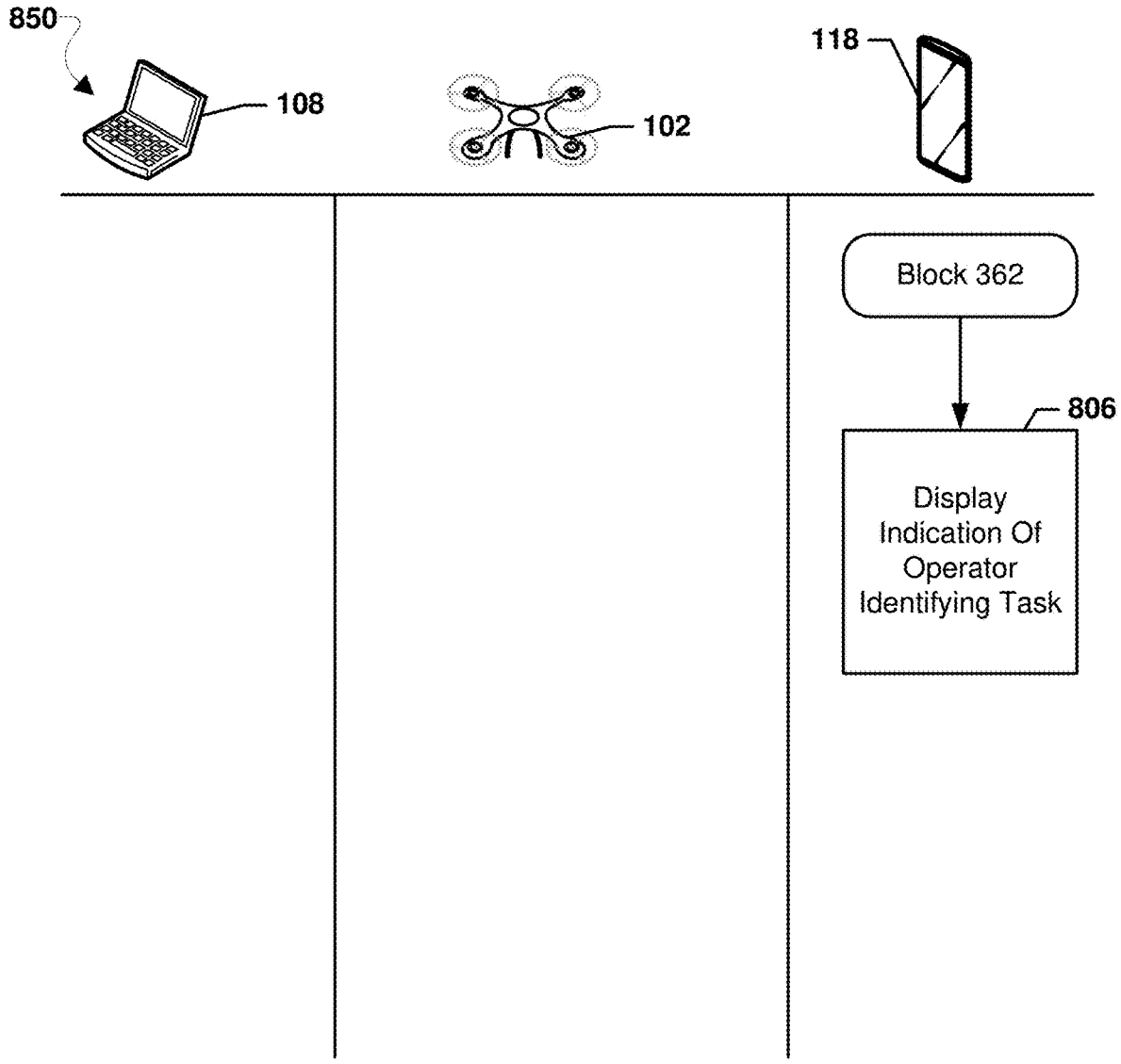
850
108
102
118
Block 362
806
Display Indication Of Operator Identifying Task

FIG. 8B

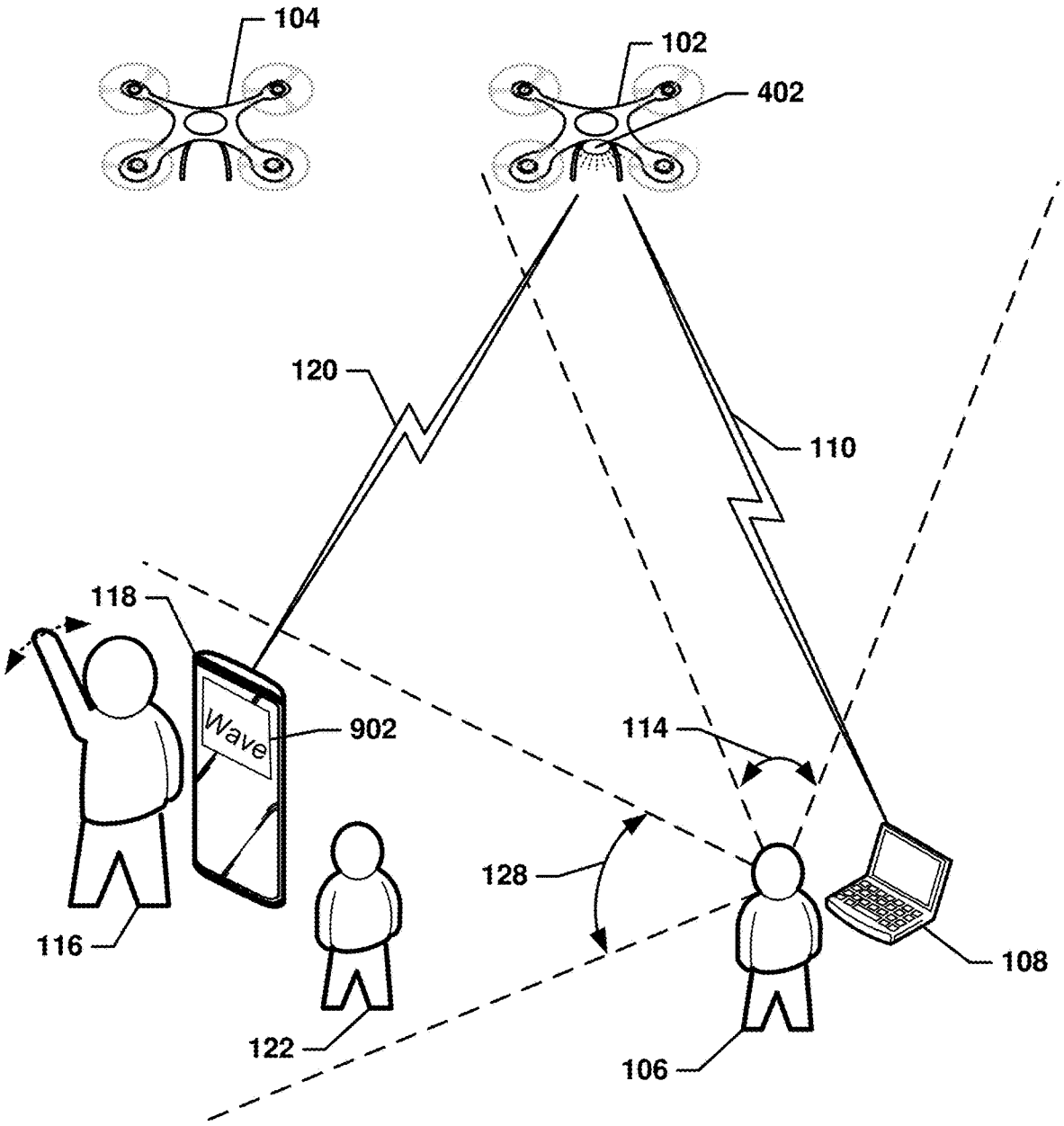

FIG. 9

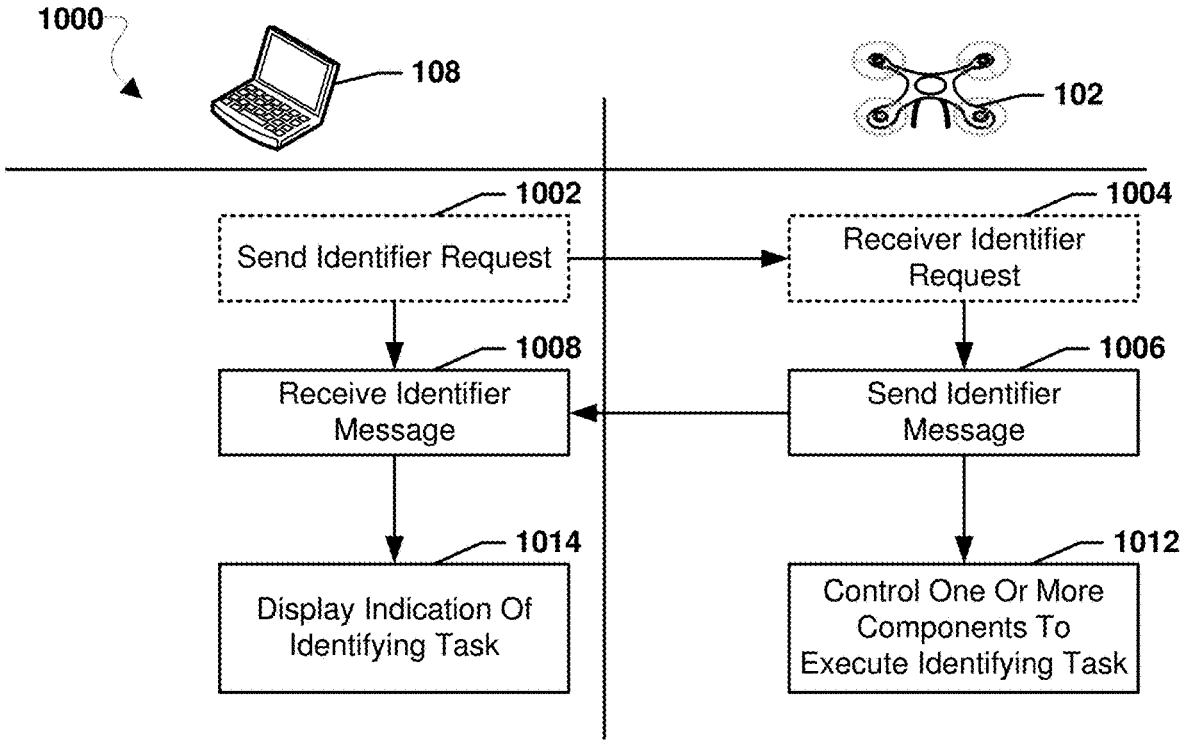
1000
108
102
1002
Send Identifier Request
1004
Receiver Identifier Request
1008
Receive Identifier Message
1006
Send Identifier Message
1014
Display Indication Of Identifying Task
1012
Control One Or More Components To Execute Identifying Task

FIG. 10

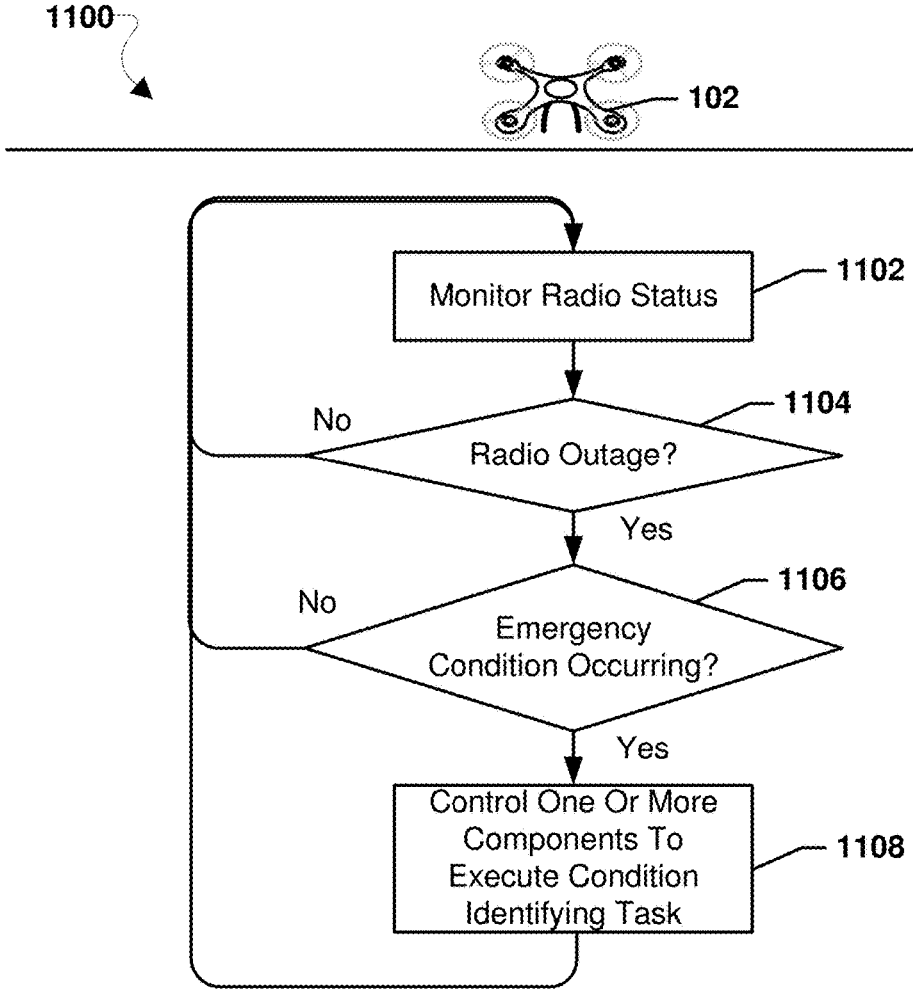
1100
102
Monitor Radio Status
1102
No
Radio Outage?
1104
Yes
No
Emergency Condition Occurring?
1106
Yes
Control One Or More Components To Execute Condition Identifying Task
1108

FIG. 11

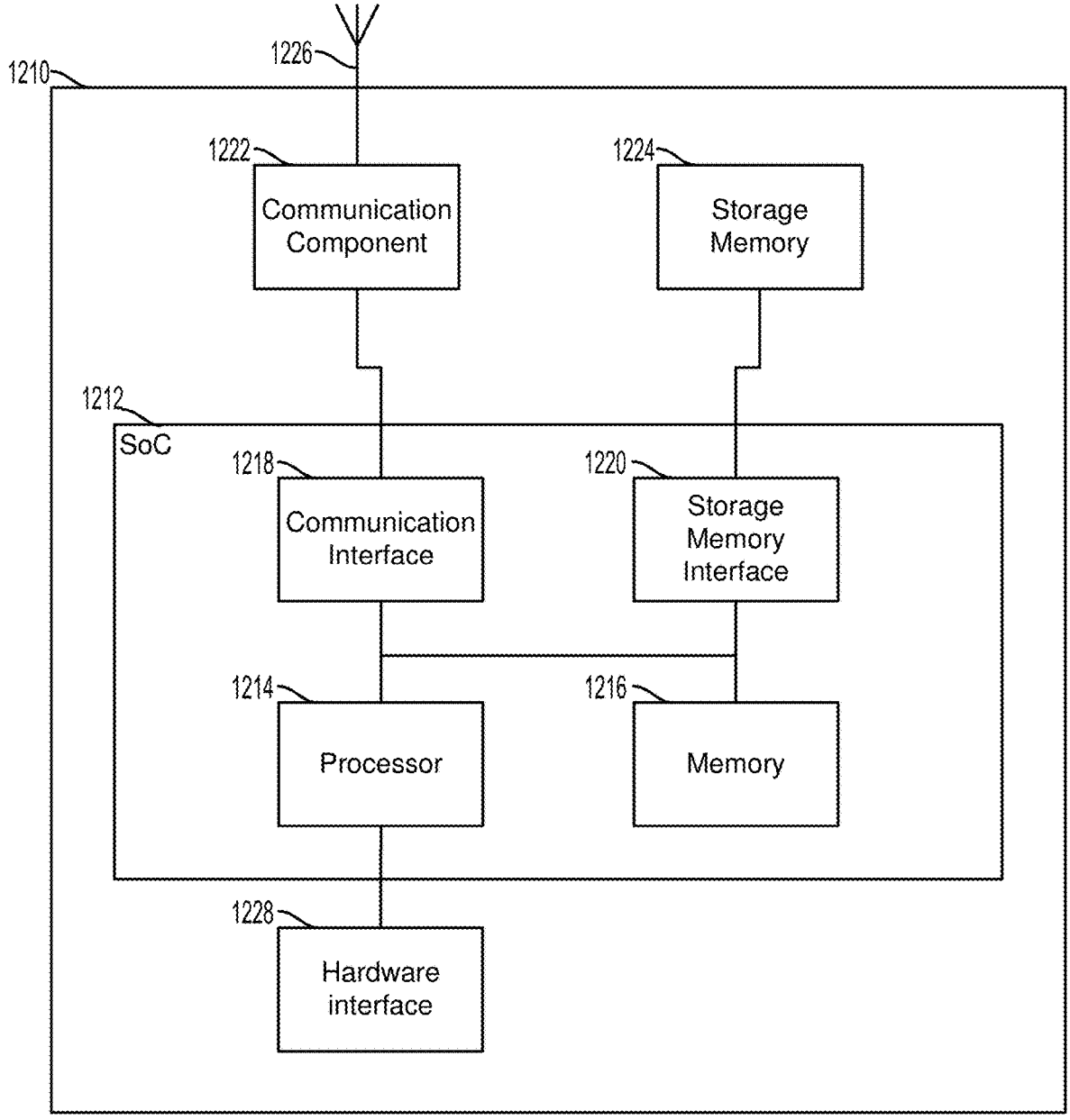
1210
1226
1222
Communication Component
1224
Storage Memory
1212
SoC
1218
Communication Interface
1220
Storage Memory Interface
1214
Processor
1216
Memory
1228
Hardware interface

FIG. 12

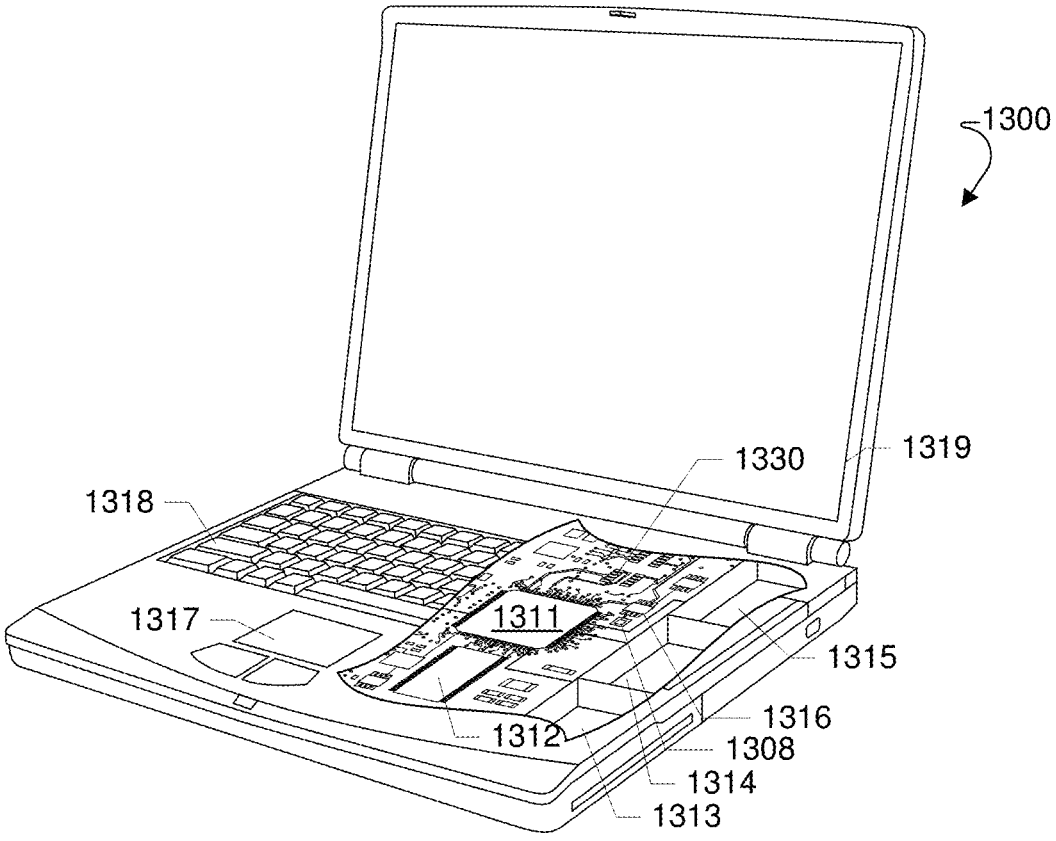

FIG. 13

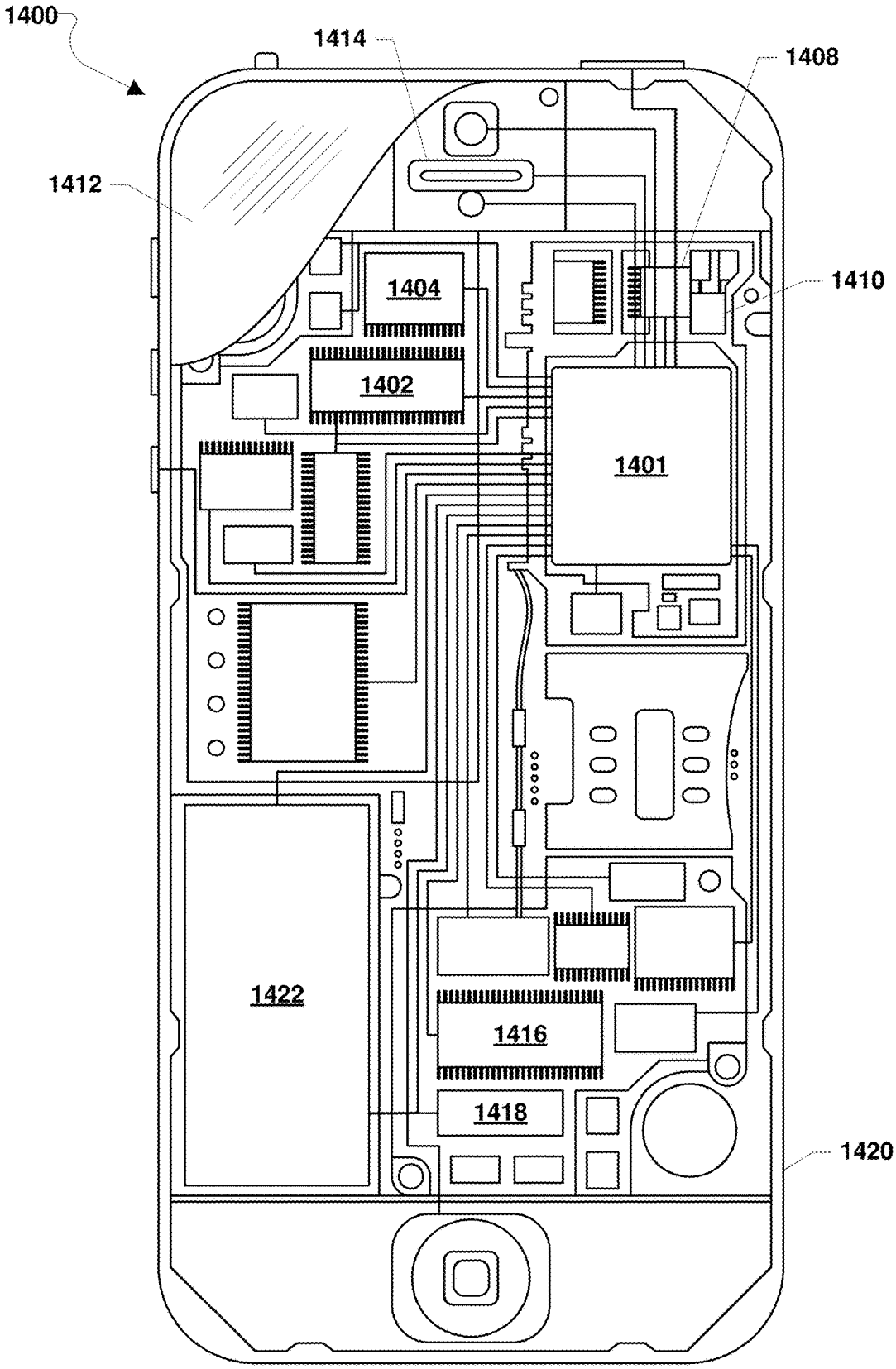

FIG. 14

LOCAL DRONE IDENTIFICATION VERIFICATION

CLAIM OF PRIORITY UNDER 35 U.S.C. § 120

This application for Patent is a continuation of U.S. application Ser. No. 15/844,925, entitled "Local Drone Identification Verification", filed Dec. 18, 2017, which claims priority to U.S. Provisional Application No. 62/524,312, filed Jun. 23, 2017, the disclosure of which is incorporated by reference herein in its entirety for all purposes.

BACKGROUND

Positively identifying robotic vehicles, such as aerial robotic vehicles, operating in a shared airspace can be difficult when many vehicles are visible, particularly when an observer is far from the robotic vehicles. Positive identifier (or "ID") mechanisms may be important for managing individual robotic vehicles, tracking regulatory compliance, and for efficiently and safely managing shared airspace resources. For example, identification of aerial robotic vehicles may be difficult in the situation of an observer attempting to wirelessly query or interact with a particular aerial robotic vehicle using a computing device when there are a number of similar looking robotic vehicles visible to the observer in a shared airspace. When several aerial robotic vehicles are operating in a shared airspace, the wireless connection between an observer's computing device does not help the observer visually distinguish one robotic vehicle among a plurality of robotic vehicles. Thus, while the observer's computing device may recognize and be able to control a particular robotic vehicle based on its identifier (ID), the observer's computing device provides no help to the observer in visually identifying and tracking the robotic vehicle.

SUMMARY

Systems, methods, and devices of the various embodiments enable local visual identification and verification of robotic vehicles. Various embodiments may enable disambiguation of a robotic vehicle from among a plurality of robotic vehicles. Various embodiments include methods that may be implemented in a processor or processing device of a robotic vehicle and that may include controlling one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver. In some embodiments, the identifying/distinguishing task or maneuver may be one action or a series of actions. In some embodiments, the one action or series of actions may be one or more of performing a maneuver, controlling a visual indicator, generating an audible indicator, and sending data. In some embodiments, controlling the visual indicator may include activating or changing a light emitting device of the robotic vehicle.

Some embodiments may include controlling one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver in response to a request from an observer's computing device that is different from an operator computing device for controlling the robotic vehicle.

Some embodiments may include receiving a disambiguation message from an observer's computing device and controlling one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver in response to receiving the disambiguation message. Some embodiments may include forwarding the disambiguation message from the processor of the robotic vehicle to an operator's computing device and receiving an instruction to execute the identifying/distinguishing task or maneuver from the operator's computing device. Some embodiments may include establishing a radio link between the robotic vehicle and the observer's computing device prior to receiving the disambiguation message. In some embodiments, the disambiguation message may be sent in response to an identifier of the robotic vehicle being validated. In some embodiments, the disambiguation message may include an operator identifying task. In some embodiments, the operator identifying task may be a gesture or motion of an operator to be performed.

Some embodiments may include receiving an execution message prior to executing the identifying/distinguishing task or maneuver.

Some embodiments may include determining whether an identifying/distinguishing task or maneuver violates one or more vehicle constraints and blocking execution of the identifying/distinguishing task or maneuver in response to determining that the identifying/distinguishing task or maneuver violates one or more vehicle constraints.

Some embodiments may include controlling one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver within an identification window of time.

Various embodiments include methods that may be implemented in a processor or processing device of a robotic vehicle and that may include sending a disambiguation message to an observer's computing device and controlling one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver.

Some embodiments may include determining whether an emergency condition is occurring and controlling one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to determining that the emergency condition is occurring. In some embodiments, the identifying/distinguishing task or maneuver may be one action or a series of actions. In some embodiments, the one action or series of actions may be one or more of performing a maneuver, controlling a visual indicator, generating an audible indicator, and sending data. In some embodiments, controlling the visual indicator may include activating or changing a light emitting device of the robotic vehicle.

Further embodiments may include a robotic vehicle having a processor configured with processor executable instructions to perform operations of any of the methods summarized above. Further embodiments may include a robotic vehicle having means for performing functions of any of the methods summarized above. Further embodiments may include a processing device configured for use in a robotic vehicle and configured to perform operations of any of the methods summarized above.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate example embodiments of the claims, and together with the general description given above and the detailed description given below, serve to explain the features of the claims.

FIG. **1** is a system block diagram of robotic vehicles operating according to various embodiments.

FIG. **2** is a component block diagram illustrating components of a robotic vehicle according to various embodiments.

FIG. **3**A is a process flow diagram illustrating a method for disambiguating a robotic vehicle according to some embodiments.

FIG. **3**B is a process flow diagram illustrating a method for disambiguating a robotic vehicle according to some embodiments.

FIG. **4**A is a system block diagram illustrating an example of a robotic vehicle identification being validated according to some embodiments.

FIG. **4**B is a system block diagram illustrating an example of a robotic vehicle identification being validated according to some embodiments.

FIG. **4**C is a system block diagram illustrating an example of a robotic vehicle identification being validated according to some embodiments.

FIG. **5** is a process flow diagram illustrating a method for disambiguating a robotic vehicle according to some embodiments.

FIG. **6**A is a process flow diagram illustrating a method for disambiguating a robotic vehicle according to some embodiments.

FIG. **6**B is a process flow diagram illustrating a method for disambiguating a robotic vehicle according to some embodiments.

FIG. **7** is a process flow diagram illustrating a method for verifying an identifying/distinguishing task or maneuver according to some embodiments.

FIG. **8**A is a process flow diagram illustrating a method for disambiguating a robotic vehicle operator according to some embodiments.

FIG. **8**B is a process flow diagram illustrating a method for disambiguating a robotic vehicle operator according to some embodiments.

FIG. **9** is a system block diagram illustrating an example of a robotic vehicle operator being identified according to some embodiments.

FIG. **10** is a process flow diagram illustrating a method for disambiguating a robotic vehicle according to some embodiments.

FIG. **11** is a process flow diagram illustrating a method for robotic vehicle emergency condition signaling according to some embodiments.

FIG. **12** is a component block diagram illustrating a processing device suitable for implementing various embodiments.

FIG. **13** is a component diagram of an example computing device suitable for use with various embodiments.

FIG. **14** is a component diagram of another example computing device suitable for use with various embodiments.

DETAILED DESCRIPTION

The various aspects will be described in detail with reference to the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. References made to particular examples and implementations are for illustrative purposes, and are not intended to limit the scope of the invention or the claims.

As used herein, the term "computing device" refers to any one or all of cellular telephones, smart phones, personal or mobile multi-media players, personal data assistants (PDAs), laptop computers, personal computers, tablet computers, smart books, palm-top computers, wireless electronic mail receivers, multimedia Internet enabled cellular telephones, wireless gaming controllers, wireless robotic vehicle controllers, satellite or cable set top boxes, streaming media players (such as, ROKU® or CHROMECAST® or FIRE TV™), smart televisions, digital video recorders (DVRs), and similar personal electronic devices which include a programmable processor and memory and circuitry configured to perform operations as described herein.

As used herein, the terms "robotic vehicle" and "drone" refer to one of various types of vehicles including an onboard computing device configured to provide some autonomous or semi-autonomous capabilities. Examples of robotic vehicles include but are not limited to: aerial vehicles, such as an unmanned aerial vehicle (UAV); ground vehicles (e.g., an autonomous or semi-autonomous car, a vacuum robot, etc.); water-based vehicles (i.e., vehicles configured for operation on the surface of the water or under water); space-based vehicles (e.g., a spacecraft or space probe); and/or some combination thereof. In some embodiments, the robotic vehicle may be manned. In other embodiments, the robotic vehicle may be unmanned. In embodiments in which the robotic vehicle is autonomous, the robotic vehicle may include an onboard computing device configured to maneuver and/or navigate the robotic vehicle without remote operating instructions (i.e., autonomously), such as from a human operator (e.g., via a remote computing device). In embodiments in which the robotic vehicle is semi-autonomous, the robotic vehicle may include an onboard computing device configured to receive some information or instructions, such as from a human operator (e.g., via a remote computing device), and autonomously maneuver and/or navigate the robotic vehicle consistent with the received information or instructions. In some implementations, the robotic vehicle may be an aerial vehicle (unmanned or manned), which may be a rotorcraft or winged aircraft. For example, a rotorcraft (also referred to as a multirotor or multicopter) may include a plurality of propulsion units (e.g., rotors/propellers) that provide propulsion and/or lifting forces for the robotic vehicle. Specific non-limiting examples of rotorcraft include tricopters (three rotors), quadcopters (four rotors), hexacopters (six rotors), and octocopters (eight rotors). However, a rotorcraft may include any number of rotors.

Positively identifying robotic vehicles, such as aerial vehicles, operating in a shared airspace can be difficult when many vehicles are visible, particularly when an observer is far from the robotic vehicles. Positive identifier (or "ID") mechanisms are essential for managing individual robotic vehicles, tracking regulatory compliance, and for efficiently and safely managing shared airspace resources. There are technologies that provide a reliable ID mechanism for identifying and authenticating the claimed identity of a robotic vehicle and/or robotic vehicle operator. Some ID mechanism technologies provide digital IDs that are based on internet protocol (IP) certificates, such as secure socket layer (SSL) certificates and transport layer security (TLS) certificates. Such digital certificates can be transmitted over many types of wireless connections, both local (e.g., Wi-Fi®, Bluetooth®, etc.) and wide-area (e.g., cellular, such as Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), Global System for Mobility (GSM), 3G, 4G, Long Term Evolution (LTE), etc.).

A particular problem arises in the situation of an observer attempting to wirelessly query or interact with a particular robotic vehicle using a computing device ("observer's computing device") while visually observing at least some

portion of the plurality of robotic vehicles in a shared airspace. When several robotic vehicles are operating in a shared airspace, the wireless connection between an observer's computing device does not help the observer visually distinguish the robotic vehicle among the plurality of robotic vehicles that is associated with the robotic vehicle identifier (ID) being tracked by the observer's computing device. Observers, such as law enforcement officers, property owners, emergency personnel, or any other individuals visually observing robotic vehicles, need to disambiguate between robotic vehicles being observed or controlled in order to ensure appropriate actions are taken in regard to a specific robotic vehicle. For example, a law enforcement officer needs to correctly differentiate a selected robotic vehicle linked to an ID from another robotic vehicle before disabling the selected robotic vehicle.

Systems, methods, and devices of the various embodiments enable local visual identification and verification of robotic vehicles. Various embodiments may enable visual disambiguation of a robotic vehicle from among a plurality of robotic vehicles. Various embodiments may enable disambiguating a robotic vehicle (e.g., an aerial vehicle) identification when multiple robotic vehicles are operating (e.g., flying, etc.) in close proximity. In some embodiments, in response to establishment of a communication channel (e.g., radio link, etc.) to an identified and authenticated robotic vehicle (e.g., a robotic vehicle with a valid identifier verified by a SSL certificate, TLS certificate, or other cryptographic token), the connected observer's computing device (e.g., a law enforcement official's laptop on the ground or any other location that allows observation of the robotic vehicles) may generate and send a disambiguation message. A disambiguation message may be a request configured to cause a robotic vehicle to execute an identifying/distinguishing task or maneuver (e.g., perform a movement and/or light flash) and a disambiguation message may be referred to as a "request". In response to receiving the disambiguation message, the robotic vehicle may execute an identifying/distinguishing task or maneuver (e.g., perform a movement and/or light flash) that enables the observer to positively identify or distinguish the connected robotic vehicle. In some embodiments, this identifying/distinguishing task or maneuver may be executed within an identification time window to enable identity disambiguation with low risk of spoofing by other vehicles.

In some embodiments, a processor of the robotic vehicle may be configured to autonomously control one or more components of the robotic vehicle to execute an identifying/distinguishing task in response to receiving a disambiguation message. In some embodiments, a processor of a robotic vehicle may forward a disambiguation message to an operator's computing device in response to receiving a disambiguation message. A processor of the operator's computing device may be configured to cause the operator's computing device to display an indication of the identifying/distinguishing task or maneuver in response to receiving the forwarded disambiguation message. For example, a display of the operator's computing device may be controlled to display a pop-up window indicating a need to perform an identifying/distinguishing task or maneuver. In response to receiving an input corresponding to the identifying/distinguishing task or maneuver from the operator, the processor of the operator's computing device may send an instruction to the processor of the robotic vehicle to execute the identifying/distinguishing task or maneuver. In response to receiving the instruction to execute the identifying/distinguishing task or maneuver, the processor of the robotic vehicle may control one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver.

In some embodiments, a disambiguation messages may be generated by a processor of an observer's computing device (e.g., a processor of a law enforcement official's laptop) in response to a user input indication. For example, in response to a user input indication corresponding to a button press event, touch screen selection, etc., the processor of the observer's computing device may generate the disambiguation message. The disambiguation message may be a request generated in response to the user input indication and configured to cause a robotic vehicle to execute an identifying/distinguishing task or maneuver (e.g., perform a movement and/or light flash).

In some embodiments, the disambiguation message may indicate the identifying/distinguishing task or maneuver to be executed by the robotic vehicle. For example, the disambiguation message may be a request to execute the indicated identifying/distinguishing task or maneuver. In some embodiments, the disambiguation message may indicate the identifying/distinguishing task or maneuver explicitly, such as by including an identifier of the identifying/distinguishing task or maneuver.

In some embodiments, the disambiguation message may obfuscate the identifying/distinguishing task or maneuver. For example, the disambiguation message may indicate the received identifier of the robotic vehicle and the robotic vehicle or observer's computing device may determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating the received identifier to a predetermined identifying/distinguishing task or maneuver (e.g., execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving the disambiguation message including a specific identifier, etc.). As a specific example, the stored instructions may include ten different identifying/distinguishing task or maneuvers correlated with numbers zero to nine, and the received identifier may indicate which of the ten identifying/distinguishing task or maneuver to perform. As another example, the disambiguation message may include a hash of the received identifier of the robotic vehicle and the robotic vehicle or observer's computing device may determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating hash values with a predetermined identifying/distinguishing task or maneuver (e.g., execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving a disambiguation message including a specific hash value, execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving a disambiguation message including a hash value matching a hash of the robotic vehicle's identifier, etc.). As a further example, the disambiguation message may include instructions for operations for the robotic vehicle or observer's computing device to perform to determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating resulting values with a predetermined identifying/distinguishing task or maneuver (e.g., the disambiguation message may include an instruction to divide the robotic vehicle's tail number by two and execute a specific predetermined identifying/distinguishing task or maneuver corresponding to the resulting value, etc.). By obfuscating the identifying/distinguishing task or maneuver in the disambiguation message, the likelihood of false positives and spoofing may be reduced.

In some embodiments, the identifying/distinguishing task or maneuver indicated in the disambiguation message may be selected automatically by the processor of the observer's computing device during disambiguation message generation. In some embodiments, the identifying/distinguishing task or maneuver indicated in the disambiguation message may be selected by the operator via user input (e.g., a touch screen selection from a dropdown menu listing available identifying/distinguishing task or maneuvers).

In some embodiments, an identifying/distinguishing task or maneuver may include one or more actions. For example, the identifying/distinguishing task or maneuver may include a maneuver for the robotic vehicle to perform (e.g., a barrel roll, wing tip, hover, climb, drop, zig-zag, etc.). As another example, the identifying/distinguishing task or maneuver may include a visual indicator for the robotic vehicle to operate, such as activate or otherwise illuminate a light or other light emitting device, turn on/off a light emitting diode (LED) or other light emitting device, flash a display or other light emitting device, change an LED or other light emitting device color, and the like. As another example, the identifying/distinguishing task or maneuver may be generating an audible indicator, such as turning on a speaker to output a sound, change a sound output by a speaker, turn on/off a horn, or the like. As a further example, the identifying/distinguishing task or maneuver may include an indication of data for the robotic vehicle to provide to the observer's computing device. As examples, the robotic vehicle may provide one or more of an image file of the robotic vehicle, a public key, information unique to the robotic vehicle (e.g., a modem serial number, etc.), current flight characteristics (e.g., altitude, heading, global positioning system (GPS) coordinates, etc.), or any other type data to assist in identifying the robotic vehicle. The observer's computing device may display the received data to the observer to assist in the observer identifying the robotic vehicle. Some identifying/distinguishing tasks or maneuvers may be more suitable for certain situations than other identifying/distinguishing task or maneuvers. For example, at some distances lights may not be visible in the daylight and a more preferable action may be to perform a barrel roll or other maneuver to enable the observer to easily identify the robotic vehicle. As another example, maneuvers may not be visible at night and flashing a light may be preferable.

In some embodiments, an identifying/distinguishing task or maneuver may include multiple actions/indications/maneuvers (e.g., a series or sequence) to be executed by a robotic vehicle. For example, a disambiguation message may require a robotic vehicle to flash an orange light emitting diode (LED), flash a LED green, and then flash the LED orange. As another example, the disambiguation message may require the robotic vehicle to flash the LED, tip a wing, and then perform a barrel roll or other specified maneuver. Identifying/distinguishing tasks or maneuvers including a series of actions may provide benefits, including that a series of actions reduces the chances of false positives since it is unlikely another robotic vehicle will randomly perform the same actions in a given identification window of time. A series of actions may make spoofing more difficult since it is unlikely to guess the sequence. Further, a series of actions may provide a more robust method of distinguishing vehicles, such as in case the observer fails to see one of the actions in the series or the robotic vehicle is not capable of performing one of the actions, performing, for example, three out of four actions in sequence may be sufficient. Also, a series of actions may allow for a larger identification window in which to respond to the disambiguation message, for example because the likelihood of false positives and spoofing may be reduced.

In some embodiments, the identification window may be a period of time during which an identifying/distinguishing task or maneuver must be executed. Identification window lengths may be any period of time, such as one second, two seconds, thirty seconds, a minute, etc. The shorter the period of time the less the likelihood of false positives or spoofing. In some embodiments, the identification window may be indicated in the disambiguation message. In some embodiments, the identification window may occur immediately upon receiving a disambiguation message. As examples, the identification window may be within two seconds after receiving a disambiguation message, within thirty seconds after receiving a disambiguation message, etc. This immediate start of the identification window may mitigate false positives, spoofing, etc.

In some embodiments, the identification window may occur a certain time after receiving a disambiguation message. For example, the identification window may start sixty seconds after receiving the disambiguation message. In some embodiments, the identification window may occur at a certain time. For example, the identification window may start at a specific GPS clock time (e.g., 7:12 pm). The period to delay the start of the identification window or the time to start the identification window may be indicated in the disambiguation message. The advantage to delaying the start of the identification window to a time after receiving the disambiguation message may be that it gives the robotic vehicle and/or robotic vehicle operator some prep time (e.g., to go to a menu that allows performing whatever identifying/distinguishing task or maneuver was requested). This delay may still prevent false positives and spoofing as any such actions before the delayed start may not suffice for authentication purposes. In some embodiments, timing synchronization may occur between one or more of the observer's computing device, robotic vehicle, and operator's computing device to support identification window timing. For example, the one or more of the observer's computing device, robotic vehicle, and operator's computing device may synchronize to GPS time.

In some embodiments, disambiguation message may indicate that the execution of the identifying/distinguishing task or maneuver is to be delayed until an execution message is received. The execution message may be a message from the observer's computing device indicating that the identifying/distinguishing task or maneuver should be executed. In this manner, the observer may state the action to perform and that the robotic vehicle/robotic vehicle operator should be prepared to receive a follow-up notification at a certain time or within a window at which the action is to be performed. For example, the disambiguation message may be a request that a LED should be flashed in response to the execution message. The observer's computing device may send the execution message as the next follow-up notification and the robotic vehicle/robotic vehicle operator may execute the identifying/distinguishing task or maneuver in response to receiving the execution message (e.g., flash the LED). The identification window may begin upon the receipt of the execution message or the execution message may indicate the identification window of time.

In some embodiments, a processor of a robotic vehicle may be configured to determine whether an identifying/distinguishing task or maneuver violates one or more vehicle constraints in response to receiving a disambiguation message. Vehicle constraints may be limitations on the opera-

tions that a robotic vehicle can perform. For example, vehicle constraints may be associated with the design of the vehicle (e.g., the vehicle aerodynamics may not support certain maneuvers, the vehicle may lack lights, etc.). As another example, vehicle constraints may be associate with the mission of the robotic vehicle (e.g., the robotic vehicle may be a military vehicle that should not turn on its lights during a mission, the robotic vehicle may be carrying a heavy and/or delicate payload limiting its maneuverability, etc.) In response to determining that a specified identifying/distinguishing task or maneuver violates one or more vehicle constraints, the processor of the robotic vehicle may block the execution of the identifying/distinguishing task or maneuver. For example, the processor may ignore or drop the disambiguation message and/or the processor may not pass the identifying/distinguishing task or maneuver to an avionics module. In some embodiments, in response to blocking the identifying/distinguishing task or maneuver execution, the processor may send an indication of the constraint violation to the observer's computing device. As examples, the indication may be a message indicating that the robotic vehicle is on a military mission, cannot perform a barrel roll, etc. In response to determining that a specified identifying/distinguishing task or maneuver violates one or more vehicle constraints, the processor of the robotic vehicle may transmit to the observer's computing device one or more (e.g., a list) alternative tasks or maneuvers that the robotic vehicle can perform instead. For example, if the processor of the robotic vehicle determines that performing a barrel roll as indicated in the disambiguation message would violate a flight control law or restriction, the processor may transmit a message to the observer's computing device suggesting an alternative action, such as "flash lights according to Morse Code Z-R-X." In some embodiments, the processor of the robotic vehicle may transmit a different suggestion for alterative task or maneuvers each time the processor determines that the identified or requested task or maneuver cannot be performed so as to reduce the risk of copying or spoofing by other vehicles.

In some embodiments, a disambiguation message may include an operator identifying task. An operator identifying task may be an indication of an action an operator of a robotic vehicle should take to identify him or herself visually. For example, an operator identifying task may be an indication to an operator of a robotic vehicle to wave his or her arm in the air, turn around, or make some other type of motion/gesture that the observer can see. In some embodiments, a processor of a robotic vehicle may be configured to forward a disambiguation message including an operator identifying task to the operator's computing device. In response to receiving the disambiguation message including an operator identifying task, the processor of the operator's computing device may display an indication of the operator identifying task. As examples, the processor may control a display or speaker of the observer's computing device to output a message of "wave an arm above your head." The observer may look for an operator waving an arm above his or her head to identify the operator associated with the robotic vehicle receiving the disambiguation message.

In some embodiments, a robotic vehicle may generate an identifier message indicating an identifying/distinguishing task or maneuver the robotic vehicle is going to execute within an identification window or is already executing. The identifier message may be periodically sent by the robotic vehicle or may be sent in response to the robotic vehicle receiving an identifier request. An observer's computing device receiving the identifier message may display an indication of the identifying/distinguishing task or maneuver. In this manner, identifying/distinguishing tasks or maneuvers may be executed and indicated to observers without needing a disambiguation message to be sent by the observer.

In some embodiments, a robotic vehicle may execute an identifying/distinguishing task or maneuver in response to an emergency condition occurring. For example, when there is a radio outage detected by the robotic vehicle and/or when an emergency condition occurs (e.g., loss of GPS, motor failure, etc.) the robotic vehicle may execute a predetermined identifying/distinguishing task or maneuver to indicate the radio outage and/or emergency condition to an observer. For example, when a radio outage has occurred and GPS is lost, the robotic vehicle may execute a predetermined identifying/distinguishing task or maneuver to flash a LED red once every three seconds. An observer or operator may see that flashing red LED at the three second interval and determine that the robotic vehicle has experience a radio outage and GPS loss. This may enable the observer or operator to take an appropriate action for the indicated emergency condition even though the emergency condition could not be communicated via radio due to the radio outage.

In some embodiments, the processor of a robotic vehicle may be configured to perform an identifying/distinguishing task or maneuver in response to the establishment of a communication link with an observer's computing device without being prompted by a disambiguation message. In some embodiments, the processor of a robotic vehicle may be configured to perform a first identifying/distinguishing task or maneuver in response to the establishment of a communication link, and then perform another (e.g., specified) identifying/distinguishing task or maneuver in response to receiving a disambiguation message. In some embodiments, the processor of a robotic vehicle may be configured to determine the identity or authority of an observer's computing device establishing a communication link with the vehicle, and perform a first identifying/distinguishing task or maneuver in response to the communication link being established by a particular person or authority (e.g., law enforcement, aviation regulatory agent, etc.).

Various embodiments may be implemented within a communication system **100** of robotic vehicles, operators and observers, an example of which is illustrated in FIG. **1**. The system **100** may include a plurality of robotic vehicles, such as robotic vehicle **102** and robotic vehicle **104**, an observer's computing device **108**, and a plurality of operator's computing devices, such as operator's computing device **118** and operator's computing device **124**. The robotic vehicle **102** may communicate with the operator's computing device **118** via a wireless communications link **120** and via the wireless communications link **120** the robotic vehicle **102** and operator's computing device **118** may exchange data with one another. The robotic vehicle **104** may communicate with the operator's computing device **124** via a wireless communications link **126**. Via this wireless communications link **126** the robotic vehicle **104** and operator's computing device **124** may exchange data with one another. The robotic vehicle **102** may communicate with the observer's computing device **108** via wireless communications link **110** and via the wireless communications link **110** the robotic vehicle **102** and observer's computing device **108** may exchange data with one another. The robotic vehicle **104** may communicate with the observer's computing device **108** via wireless communications link **112** and via the wireless communications link **112** the robotic vehicle **104** and observer's com-

puting device **108** may exchange data with one another. The data exchanged via the various wireless communications links **110**, **112**, **120**, **126** may include messages, such as disambiguation messages, identifier requests, identifiers, identifier messages, execution messages, instructions, etc.

The wireless communications links **110**, **112**, **120**, **126** may be direct (device-to-device) wireless links or may be wireless communication links established via various wireless network connections (e.g., cellular data networks, Wi-Fi wireless local area networks (WLAN), etc.).

For example, connections to base stations and access points may provide the wireless communications links **110**, **112**, **120**, **126**. The base stations may include base stations configured to provide wireless communications over a wide area (e.g., macro cells), as well as small cells, which may include a micro cell, a femto cell, a pico cell, and other similar network access points. The access points may be configured to provide wireless communications over a relatively smaller area. Other examples of base stations and access points are also possible.

The wireless communications links **110**, **112**, **120**, **126** may include a plurality of carrier signals, frequencies, or frequency bands, each of which may include a plurality of logical channels. The wireless communications links **110**, **112**, **120**, **126** may utilize one or more radio access technologies (RATs). Examples of RATs that may be used in a wireless communication link include CDMA, TDMA, GSM, 3G, 4G, LTE, and other cellular RATs. Further examples of RATs that may be used in one or more of the various wireless communications links **110**, **112**, **120**, **126** include medium range protocols such as Wi-Fi, LTE-U, LTE-Direct, LAA, MuLTEfire, and relatively short-range RATs such as ZigBee, Bluetooth, and Bluetooth Low Energy (LE).

The observer's computing device **108** may be operated by an operator **106** with a line of sight **114** (e.g., a field of vision) in which both robotic vehicle **102** and robotic vehicle **104** are visible. Additionally, in a line of sight **128** (e.g., a field of vision) of the observer **106**, both an operator **116** operating the operator's computing device **118** and an operator **122** operating the operator's computing device **124** may be visible. As two robotic vehicles **102**, **104** and two operators **116**, **122** may be visible to the observer **106**, wireless communications of an identifier between the observer's computing device **108** and the robotic vehicles **102**, **104** alone may not enable the observer **106** to disambiguate between the robotic vehicles **102**, **104**.

Execution of an identifying/distinguishing task or maneuver by one of the robotic vehicles **102** and **104** in the line of sight **114** of the observer **106** may enable the observer to distinguish between the robotic vehicles **102**, **104**. Execution of an operator identifying task by one of the operators **116**, **122** in the line of sight **128** of the observer **106** may enable the observer to distinguish between the operators **116**, **122**. Execution of an identifying/distinguishing task or maneuver by one of the robotic vehicles **102** and **104** in the line of sight **114** of the observer **106** in conjunction with execution of an operator identifying task by one of the operators **116**, **122** in the line of sight **128** of the observer **106** may enable the observer to identify a particular one of the robotic vehicles **102**, **104** operated by a corresponding operator **116**, **122**. Execution of an identifying/distinguishing task or maneuver by one of the robotic vehicles **102** and **104** in the line of sight **114** of the observer **106** and/or a line of sight of an operator **116**, **122** may enable the observer **106** and/or operator **116**, **122** to determine an emergency condition of the robotic vehicles **102**, **104**.

Robotic vehicles may include winged or rotorcraft varieties of aerial robotic vehicles. FIG. **2** illustrates an example of a robotic vehicle **200**, such as an aerial robotic vehicle, that utilizes multiple rotors **202** driven by corresponding motors to provide lift-off (or take-off) as well as other aerial movements (e.g., forward progression, ascension, descending, lateral movements, tilting, rotating, etc.). The robotic vehicle **200** is illustrated as an example of a robotic vehicle that may utilize various embodiments, but is not intended to imply or require that various embodiments are limited to aerial robotic vehicles or rotorcraft robotic vehicles. Various embodiments may be used with winged robotic vehicles, land-based autonomous vehicles, water-borne autonomous vehicles, space-based autonomous vehicles, etc.

With reference to FIGS. **1** and **2**, the robotic vehicle **200** may be similar to the robotic vehicle **102** and robotic vehicle **104**. The robotic vehicle **200** may include a number of rotors **202**, a frame **204**, landing columns **206** or skids, and one or more indicators **251**, such as one or more LEDs, one or more incandescent bulb lights, one or more display screens, one or more speakers, one or more horns, one or more buzzers or bells, etc. The frame **204** may provide structural support for the motors associated with the rotors **202**. The landing columns **206** may support the maximum load weight for the combination of the components of the robotic vehicle **200** and, in some cases, a payload. For ease of description and illustration, some detailed aspects of the robotic vehicle **200** are omitted such as wiring, frame structure interconnects, or other features that would be known to one of skill in the art. For example, while the robotic vehicle **200** is shown and described as having a frame **204** having a number of support members or frame structures, the robotic vehicle **200** may be constructed using a molded frame in which support is obtained through the molded structure. While the illustrated robotic vehicle **200** has four rotors **202**, this is merely exemplary and various embodiments may include more or fewer than four rotors **202**.

The robotic vehicle **200** may further include a control unit **210** that may house various circuits and devices used to power and control the operation of the robotic vehicle **200**. The control unit **210** may include a processor **220**, a power module **230**, sensors **240**, one or more cameras **244**, an output module **250**, an input module **260**, and a radio module **270**. Optionally, the control unit may also include one or more of the indicators **251**. The power module **230**, sensors **240**, one or more cameras **244**, output module **250**, input module **260**, radio module **270**, and/or one or more indicators **251** may be connected to the processor **220**.

The processor **220** may be configured with processor-executable instructions to control travel and other operations of the robotic vehicle **200**, including operations of various embodiments. The processor **220** may include or be coupled to a navigation unit **222**, a memory **224**, a gyro/accelerometer unit **226**, and an avionics module **228**. The processor **220** and/or the navigation unit **222** may be configured to communicate with another computing device (e.g., operator's computing device **118**, **124**, observer's computing device **108**, etc.) through wireless communications links, such as wireless communications links **110**, **112**, **120**, **126**.

The avionics module **228** may be coupled to the processor **220** and/or the navigation unit **222**, and may be configured to provide travel control-related information such as altitude, attitude, airspeed, heading, and similar information that the navigation unit **222** may use for navigation purposes, such as dead reckoning between Global Navigation Satellite System (GNSS) position updates. The gyro/accelerometer unit **226** may include an accelerometer, a gyro-

scope, an inertial sensor, or other similar sensors. The avionics module **228** may include or receive data from the gyro/accelerometer unit **226** that provides data regarding the orientation and accelerations of the robotic vehicle **200** that may be used in navigation and positioning calculations, as well as providing data used in various embodiments.

The processor **220** may further receive additional information from the sensors **240**, such as an image sensor or optical sensor (e.g., a sensor capable of sensing visible light, infrared, ultraviolet, and/or other wavelengths of light). The sensors **240** may also include a radio frequency (RF) sensor, a barometer, a humidity sensor, a sonar emitter/detector, a radar emitter/detector, a microphone or another acoustic sensor, a lidar sensor, a time-of-flight (TOF) 3-D camera, or another sensor that may provide information usable by the processor **220** for movement operations, navigation and positioning calculations, and determining environmental conditions. The sensors **240** may also include one or more sensors configured to detect temperatures generated by one or more robotic vehicle components, such as thermometers, thermistors, thermocouples, positive temperature coefficient sensors, and other sensor components.

The power module **230** may include one or more batteries that may provide power to various components, including the processor **220**, the sensors **240**, the one or more cameras **244**, the output module **250**, the input module **260**, the one or more indicators **251**, and the radio module **270**. In addition, the power module **230** may include energy storage components, such as rechargeable batteries. The processor **220** may be configured with processor-executable instructions to control the charging of the power module **230** (i.e., the storage of harvested energy), such as by executing a charging control algorithm using a charge control circuit. Alternatively or additionally, the power module **230** may be configured to manage its own charging. The processor **220** may be coupled to the output module **250**, which may output control signals for managing the motors that drive the rotors **202** and other components (including one or more indicators **251** if not connected directly to the processor **220**).

The robotic vehicle **200** may be controlled through control of the individual motors of the rotors **202** as the robotic vehicle **200** progresses toward a destination. The control of the individual motors of the rotors **202** may enable the robotic vehicle to perform maneuvers (e.g., barrel rolls, dips, climbs, loops, etc.) The processor **220** may receive data from the navigation unit **222** and use such data in order to determine the present position and orientation of the robotic vehicle **200**, as well as the appropriate course towards the destination or intermediate sites. In various embodiments, the navigation unit **222** may include a GNSS receiver system (e.g., one or more GPS receivers) enabling the robotic vehicle **200** to navigate using GNSS signals. Alternatively or in addition, the navigation unit **222** may be equipped with radio navigation receivers for receiving navigation beacons or other signals from radio nodes, such as navigation beacons (e.g., very high frequency (VHF) omni-directional range (VOR) beacons), Wi-Fi access points, cellular network sites, radio station, remote computing devices, other robotic vehicles, etc.

The radio module **270** may be configured to receive navigation signals, such as signals from aviation navigation facilities, etc., and provide such signals to the processor **220** and/or the navigation unit **222** to assist in robotic vehicle navigation. In various embodiments, the navigation unit **222** may use signals received from recognizable RF emitters (e.g., AM/FM radio stations, Wi-Fi access points, and cellular network base stations) on the ground.

The navigation unit **222** may include a planning application that may perform calculations to plan a path of motion for the robotic vehicle within a volumetric space ("path planning"). In some embodiments, the planning application may perform path planning using information including information about aspects of a task to be performed by the robotic vehicle, environmental condition information, an amount of heat that may be generated by one or more components of the robotic vehicle in performing the task, as well as one or more thermal constraints.

The radio module **270** may include a modem **274** and a transmit/receive antenna **272**. The radio module **270** may be configured to conduct wireless communications with a variety of wireless communication devices (e.g., a wireless communication device (WCD) **290**), examples of which include a wireless telephony base station or cell tower (e.g., a base station), a network access point (e.g., an access point), a beacon, a smartphone, a tablet, a laptop, or another computing device with which the robotic vehicle **200** may communicate. As specific examples, the WCD **290** may be the operator's computing devices **118**, **124** or observer's computing device **108**. The processor **220** may establish a bi-directional wireless communication link **294** via the modem **274** and the antenna **272** of the radio module **270** and the WCD **290** via a transmit/receive antenna **292**. In some embodiments, the radio module **270** may be configured to support multiple connections with different wireless communication devices using different radio access technologies.

In some embodiments, the WCD **290** may be connected to a server through intermediate access points. In an example, the WCD **290** may be a server of a robotic vehicle operator, a third-party service (e.g., package delivery, billing, etc.), or a site communication access point. The robotic vehicle **200** may communicate with a server through one or more intermediate communication links, such as a wireless telephony network that is coupled to a wide area network (e.g., the Internet) or other communication devices. In some embodiments, the robotic vehicle **200** may include and employ other forms of radio communication, such as mesh connections with other robotic vehicles or connections to other information sources (e.g., balloons or other stations for collecting and/or distributing weather or other data harvesting information).

In various embodiments, the control unit **210** may be equipped with an input module **260**, which may be used for a variety of applications. For example, the input module **260** may receive images or data from an onboard camera **244** or sensor, or may receive electronic signals from other components (e.g., a payload).

While various components of the control unit **210** are illustrated as separate components, some or all of the components (e.g., the processor **220**, the output module **250**, the radio module **270**, and other units) may be integrated together in a single device or module, such as a system-on-chip module.

FIG. **3**A illustrates a method **300** for disambiguating a robotic vehicle according to some embodiments. With reference to FIGS. **1-3**A, the method **300** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**) and/or the robotic vehicle (e.g., **102**, **104**, **200**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle and/or observer's computing device.

In block **301**, the observer's computing device processor may generate a disambiguation message. A disambiguation

message may be a request configured to cause a robotic vehicle to execute an identifying/distinguishing task or maneuver (e.g., perform a movement and/or light flash). In some embodiments, a disambiguation messages may be generated by a processor of an observer's computing device (e.g., a processor of a law enforcement official's laptop) in response to a user input indication. For example, in response to a user input indication corresponding to a button press event, touch screen selection, etc., the processor of the observer's computing device may generate a disambiguation message.

In some embodiments, the disambiguation message may indicate an identifying/distinguishing task or maneuver to be executed by the robotic vehicle. In some embodiments, the disambiguation message may indicate the identifying/distinguishing task or maneuver explicitly, such as by including an identifier of the identifying/distinguishing task or maneuver.

In some embodiments, the disambiguation message may obfuscate the identifying/distinguishing task or maneuver. For example, the disambiguation message may indicate the received identifier of the robotic vehicle. As another example, the disambiguation message may include a hash of the received identifier of the robotic vehicle. As a further example, the disambiguation message may include instructions for operations for the robotic vehicle or observer's computing device to perform in order to determine the particular identifying/distinguishing task or maneuver to be performed.

In some embodiments, the identifying/distinguishing task or maneuver indicated in the disambiguation message may be selected automatically by the processor of the observer's computing device during generation of the disambiguation message generation. In some embodiments, the identifying/distinguishing task or maneuver indicated in the disambiguation message may be selected by the operator and indicated by a user input indication (e.g., a touch screen selection from a dropdown menu listing available identifying/distinguishing task or maneuvers).

In block **302**, the observer's computing device processor may send the disambiguation message. For example, the disambiguation message may be sent via the wireless communication path **110**, **112**. By sending the disambiguation message, the observer's computing device processor may send a request for the robotic vehicle to execute the identifying/distinguishing task or maneuver. In block **304**, the robotic vehicle processor may receive the disambiguation message.

In block **306**, the robotic vehicle processor may control one or more components to execute the identifying/distinguishing task or maneuver. The processor of the robotic vehicle may be configured to autonomously control one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to receiving a disambiguation message. In this manner, an observer (such as observer **106**) may disambiguate the robotic vehicle based at least in part on the execution of the identifying/distinguishing task or maneuver.

In some embodiments, the robotic vehicle processor may process the disambiguation message in block **306** to determine the identifying/distinguishing task or maneuver as part of controlling one or more components to execute the identifying/distinguishing task or maneuver. As an example, the robotic vehicle processor may extract an indication of the identifying/distinguishing task or maneuver from the disambiguation message.

As another example, the disambiguation message may indicate the received identifier of the robotic vehicle and as part of the operations in block **306** the robotic vehicle may determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating the received identifier to a predetermined identifying/distinguishing task or maneuver (e.g., execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving the disambiguation message including a specific identifier, etc.). As a specific example, the stored instructions may include ten different identifying/distinguishing task or maneuvers correlated with numbers zero to nine, and the received identifier may indicate which of the ten identifying/distinguishing task or maneuver to perform. As another example, the disambiguation message may include a hash of the received identifier of the robotic vehicle and the robotic vehicle may determine the particular identifying/distinguishing task or maneuver to be performed based on stored instructions, such as stored instructions correlating hash values with a predetermined identifying/distinguishing task or maneuver (e.g., execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving a disambiguation message including a specific hash value, execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving a disambiguation message including a hash value matching a hash of the robotic vehicle's identifier, etc.). As a further example, the disambiguation message may include instructions for operations for the robotic vehicle to perform in order to determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating resulting values with a predetermined identifying/distinguishing task or maneuver (e.g., the disambiguation message may include an instruction to divide the robotic vehicle's tail number by two and execute a specific predetermined identifying/distinguishing task or maneuver corresponding to the resulting value, etc.).

In some embodiments, an identifying/distinguishing task or maneuver may include one or more actions. For example, the identifying/distinguishing task or maneuver may include a maneuver for the robotic vehicle to perform (e.g., a barrel roll, wing tip, hover, climb, drop, zig-zag, etc.). As another example, the identifying/distinguishing task or maneuver may include a visual indicator for the robotic vehicle to operate (e.g., activate a light or other light emitting device, turn on/off a light emitting diode (LED) or other light emitting device, flash a display or other light emitting device, change a LED or other light emitting device color, etc.). As another example, the identifying/distinguishing task or maneuver may include generating an audible indicator by the robotic vehicle (e.g., activating a speaker to output a sound, changing a sound output by a speaker, turning on/off a horn, etc.). As a further example, the identifying/distinguishing task or maneuver may include an indication of data for the robotic vehicle to provide to the observer's computing device. As examples, the robotic vehicle may provide one or more of an image file of the robotic vehicle, a public key, information unique to the robotic vehicle (e.g., a modem serial number, etc.), current flight characteristics (e.g., altitude, heading, global positioning system (GPS) coordinates, etc.) or any other type data to assist in identifying the robotic vehicle. The observer's computing device may display the received data to the observer to assist in the observer identifying the robotic vehicle.

In some embodiments, an identifying/distinguishing task or maneuver may include multiple actions/indications (e.g., a series or sequence) to be executed by a robotic vehicle. For example, in a disambiguation message may require that a robotic vehicle may have to flash light emitting diode (LED) orange, flash the LED green, and then flash the LED orange. As another example, the disambiguation message may require the robotic vehicle flash the LED, tip a wing, and then perform a barrel roll or other specified maneuver.

In some embodiments, the identification window may be a period of time in which an identifying/distinguishing task or maneuver must be executed. In some embodiments, the robotic vehicle processor may control one or more components to execute the identifying/distinguishing task or maneuver within the identification window of time. Identification window lengths may be any period of time, such as one second, two seconds, thirty seconds, a minute, etc. In some embodiments, the identification window may occur immediately upon receiving a disambiguation message. As examples, the identification window may be within two seconds after receiving a disambiguation message, within thirty seconds after receiving a disambiguation message, etc. In some embodiments, the identification window may occur a certain time after receiving a disambiguation message. For example, the identification window may start sixty seconds after receiving the disambiguation message. In some embodiments, the identification window may occur at a certain time. For example, the identification window may start at a specific GPS clock time (e.g., 7:12 pm). The period to delay the start of the identification window or the time to start the identification window may be indicated in the disambiguation message. In some embodiments, timing synchronization may occur between one or more of the observer's computing device and robotic vehicle, to support identification window timing.

FIG. **3**B illustrates a method **350** for disambiguating a robotic vehicle according to some embodiments. With reference to FIGS. **1**-**3**B, the method **350** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**), the robotic vehicle (e.g., **102**, **104**, **200**), and/or an operator's computing device (e.g., operator's computing device **118**, **124**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle, observer's computing device, and/or operator's computing device.

In blocks **301**, **302**, and **304** the processors of the observer's computing device and robotic vehicle may perform like operations of like numbered blocks of the method **300** as described.

In block **352**, the processor of the robotic vehicle may forward the disambiguation message to the processor of the operator's computing device. For example, the disambiguation message may be sent via the wireless communication path **120**, **126**. In block **356**, the operator's computing device processor may receive the disambiguation message.

In block **358**, the processor of the operator's computing device may display an indication of the identifying/distinguishing task or maneuver. For example, a display of the operator's computing device may be controlled to output a pop-up window indicating a need to perform an identifying/distinguishing task or maneuver. In this manner, the operator (e.g., **118**, **124**) may be notified of the identifying/distinguishing task or maneuver to be executed and in response may take an action to execute the identifying/distinguishing task or maneuver. In some embodiments, the operator's computing device may process the disambiguation message to determine the identifying/distinguishing task or maneuver as part of displaying the indication of the identifying/distinguishing task or maneuver. As an example, the operator's computing device processor may extract an indication of the identifying/distinguishing task or maneuver from the disambiguation message. As another example, the disambiguation message may indicate the received identifier of the robotic vehicle and the operator's computing device may determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating the received identifier to a predetermined identifying/distinguishing task or maneuver (e.g., execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving the disambiguation message including a specific identifier, etc.).

As a specific example, the stored instructions may include ten different identifying/distinguishing task or maneuvers correlated with numbers zero to nine, and the received identifier may indicate which of the ten identifying/distinguishing task or maneuver to perform. As another example, the disambiguation message may include a hash of the received identifier of the robotic vehicle and the operator's computing device processor may determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating hash values with a predetermined identifying/distinguishing task or maneuver (e.g., execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving a disambiguation message including a specific hash value, execute a specific predetermined identifying/distinguishing task or maneuver in response to receiving a disambiguation message including a hash value matching a hash of the robotic vehicle's identifier, etc.). As a further example, the disambiguation message may include instructions for operations for the operator's computing device processor to perform to determine the identifying/distinguishing task or maneuver based on stored instructions, such as stored instructions correlating resulting values with a predetermined identifying/distinguishing task or maneuver (e.g., the disambiguation message may include an instruction to divide the robotic vehicle's tail number by two and execute a specific predetermined identifying/distinguishing task or maneuver corresponding to the resulting value, etc.).

In some embodiments, an identifying/distinguishing task or maneuver may include one or more actions. For example, the identifying/distinguishing task or maneuver may include a maneuver for the robotic vehicle to perform (e.g., a barrel roll, wing tip, hover, climb, drop, zig-zag, etc.). As another example, the identifying/distinguishing task or maneuver may include a visual indicator for the robotic vehicle to operate (e.g., activate a light or other light emitting device, turn on/off a light emitting diode (LED) or other light emitting device, flash a display or other light emitting device, change a LED or other light emitting device color, etc.). As another example, the identifying/distinguishing task or maneuver may include generating an audible indicator by the robotic vehicle (e.g., activating a speaker to output a sound, changing a sound output by a speaker, turning on/off a horn, etc.). As a further example, the identifying/distinguishing task or maneuver may include an indication of data for the robotic vehicle or operator's computing device to provide to the observer's computing device. As examples, the robotic vehicle or operator's computing device may provide one or more of an image file of the robotic vehicle, a public key, information unique to the robotic vehicle (e.g., a modem serial number, etc.), current flight characteristics (e.g., altitude, heading, global position-

ing system (GPS) coordinates, etc.) or any other type data to assist in identifying the robotic vehicle. The observer's computing device may display the received data to the observer to assist in the observer identifying the robotic vehicle.

In some embodiments, an identifying/distinguishing task or maneuver may include multiple actions/indications (e.g., a series or sequence) to be executed by a robotic vehicle. For example, in a disambiguation message may require that a robotic vehicle may have to flash light emitting diode (LED) orange, flash the LED green, and then flash the LED orange. As another example, the disambiguation message may require the robotic vehicle flash the LED, tip a wing, and then perform a barrel roll or other specified maneuver.

In some embodiments, the identification window may be a period of time in which an identifying/distinguishing task or maneuver must be executed. In some embodiments, the operator must send instructions to cause the robotic vehicle to execute the identifying/distinguishing task or maneuver within the identification window of time. Identification window lengths may be any period of time, such as one second, two seconds, thirty seconds, a minute, etc. In some embodiments, the identification window may occur immediately upon receiving a disambiguation message. As examples, the identification window may be within two seconds after receiving a disambiguation message, within thirty seconds after receiving a disambiguation message, etc. In some embodiments, the identification window may occur a certain time after receiving a disambiguation message. For example, the identification window may start sixty seconds after receiving the disambiguation message. In some embodiments, the identification window may occur at a certain time. For example, the identification window may start at a specific GPS clock time (e.g., 7:12 pm). The period to delay the start of the identification window or the time to start the identification window may be indicated in the disambiguation message. In some embodiments, timing synchronization may occur between one or more of the observer's computing device, robotic vehicle, and observer's computing device to support identification window timing.

In block **360**, the processor of the operator's computing device may receive an input corresponding to the identifying/distinguishing task or maneuver. The input corresponding to the identifying/distinguishing task or maneuver from the operator may be a button press, menu selection of an action on a touch screen, etc.

In block **362**, the processor of the operator's computing device may send an instruction to execute the identifying/distinguishing task or maneuver to the processor of the robotic vehicle processor. For example, the instruction may be sent via the wireless communication path **120**, **126**.

In block **364**, the robotic vehicle processor may receive the instruction to execute the identifying/distinguishing task or maneuver.

In block **368**, the robotic vehicle processor may control one or more components to execute the identifying/distinguishing task or maneuver. The robotic vehicle processor may process the instruction to execute the identifying/distinguishing task or maneuver and/or the robotic vehicle may execute the identifying/distinguishing task or maneuver in a similar manner to that described with reference to block **306** of the method **300** as described. In this manner, an observer (such as observer **106**) may disambiguate the robotic vehicle based at least in part on the execution of the identifying/distinguishing task or maneuver.

FIG. **4**A illustrates an example of a robotic vehicle **102** identification being validated according to an embodiment. With reference to FIGS. **1**-**4**A, the identification validation may be performed according to operations of the methods **300** and/or **350**. For example, the disambiguation message from the observer's computing device **108** may result in the robotic vehicle **102** flashing a light **402**. In this manner, the observer **106** may determine that robotic vehicle **102**, rather than robotic vehicle **104**, is the connected robotic vehicle because robotic vehicle **102** is flashing a light **402** as indicated in the disambiguation message and robotic vehicle **104** is not.

FIG. **4**B illustrates another example of a robotic vehicle **102** identification being validated according to an embodiment. With reference to FIGS. **1**-**4**B, the identification validation may be performed according to operations of the methods **300** and/or **350**. For example, the disambiguation message from the observer's computing device **108** may result in the robotic vehicle **102** flying a loop path **404**. In this manner, the observer **106** may determine that robotic vehicle **102**, rather than robotic vehicle **104**, is the connected robotic vehicle because robotic vehicle **102** is flying a loop path **404** as indicated in the disambiguation message and robotic vehicle **104** is not.

FIG. **4**C illustrates another example of a robotic vehicle **102** identification being validated according to an embodiment. With reference to FIGS. **1**-**4**C, the identification validation may be performed according to operations of the methods **300** and/or **350**. For example, the disambiguation message from the observer's computing device **108** may result in the robotic vehicle **102** sending data to the observer's computing device **108**, such as an image **406** of the robotic vehicle **102**. In this manner, the observer **106** may determine that robotic vehicle **102**, rather than robotic vehicle **104**, is the connected robotic vehicle because robotic vehicle **102** looks like the image **406**, while robotic vehicle **104** may not look like the image **406**.

In some embodiments, the examples illustrated in FIGS. **4**A-**4**C may be combined. For example, robotic vehicle **102** may flash light **402**, fly a loop path **404**, and send image **406** all in response to the disambiguation message.

FIG. **5** illustrates a method **500** for disambiguating a robotic vehicle according to some embodiments. With reference to FIGS. **1**-**5**, the method **500** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**) and/or the robotic vehicle (e.g., **102**, **104**, **200**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle and/or observer's computing device. In some embodiments, the operations of the method **500** may be performed in conjunction with the operations of the methods **300** and/or **350**.

In optional block **502**, the observer's computing device processor may send an identifier request. An identifier request may be a message requesting a robotic vehicle receiving the message send an identifier of the robotic vehicle. In optional block **504**, the robotic vehicle processor may receive the identifier request. For example, identifier request may be sent/received via the wireless communication path **110**, **112**. Blocks **502** and **504** may be optional because robotic vehicles may not need to be interrogated to send identifiers, and in some embodiments robotic vehicles may continually or periodically transmit their respective identifiers automatically.

In block **506**, the robotic vehicle processor may send the identifier of the robotic vehicle. This identifier may be a unique ID to the robotic vehicle, such as a tail number, media access control (MAC) address, identification friend or

foe (IFF) code, or other ID and may include or be associated with a SSL certificate, TLS certificate, or other cryptographic token. For example, identifier may be sent via the wireless communication path **110**, **112**.

In block **508**, the observer's computing device processor may receive the identifier of the robotic vehicle.

In determination block **509**, the observer's computing device processor may determine whether the identifier is valid. For example, the observer's computing device processor may compare the identifier to known valid identifiers or other validation information (e.g., generate a hash value with a token and compare that to a known good hash, etc.).

In response to determining that the identifier is not valid (i.e., determination block **509**="No"), the processor may indicate an error in block **510**.

In response to validating the identifier (i.e., determination block **509**="Yes"), the observer's computing device processor and robotic vehicle processors may establish a radio link with one another in blocks **511** and **512** and execute operations of the method **300** in block **301** and **304**, respectively, as described.

FIG. **6**A illustrates a method for disambiguating a robotic vehicle according to some embodiments. With reference to FIGS. **1-6**A, the method **600** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**) and/or the robotic vehicle (e.g., **102**, **104**, **200**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle and/or observer's computing device. In some embodiments, the operations of the method **600** may be performed in conjunction with the operations of the methods **300**, **350**, and/or **500**. In some embodiments, the operations of the method **600** may be performed subsequent to the operations of blocks **302** and **304**.

In block **602**, the processor of the observer's computing device may send an execution message, and in block **604** the processor of the robotic vehicle may receive the execution message. In some embodiments, disambiguation message may indicate that the execution of the identifying/distinguishing task or maneuver is to be delayed until an execution message is received. The execution message may be a message from the observer's computing device indicating that the identifying/distinguishing task or maneuver should be executed. In this manner, the observer may state the action to perform and that the robotic vehicle/robotic vehicle operator should be prepared to receive a follow-up notification at a certain time or within a window at which the action is to be performed. For example, the disambiguation message may be a request that a LED should be flashed in response to the execution message. The observer's computing device may send the execution message as the next follow-up notification and the robotic vehicle may execute the identifying/distinguishing task or maneuver in response to receiving the execution message (e.g., flash the LED). The identification window may begin upon the receipt of the execution message or the execution message may indicate the identification window of time.

FIG. **6**B illustrates a method for disambiguating a robotic vehicle according to some embodiments. With reference to FIGS. **1-6**B, the method **650** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**), the robotic vehicle (e.g., **102**, **104**, **200**), and/or an operator's computing device (e.g., operator's computing device **118**, **124**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle, observer's computing device, and/or operator's computing device. In some embodiments, the operations of the method **650** may be performed in conjunction with the operations of the methods **300**, **350**, **500**, and/or **600**. In some embodiments, the operations of the method **650** may be performed subsequent to the operations of blocks **302**, **352**, and **358**.

In block **602**, the processor of the observer's computing device may send an execution message, and in block **604** the processor of the robotic vehicle may receive the execution message.

In block **652**, the processor of the robotic vehicle may forward the execution message to the operator's computing device, and in block **654** the operator's computing device processor may receive the execution message.

In block **656**, the operator's computing device may display an indication to execute. In this manner, the operator may be notified to execute the identifying/distinguishing task or maneuver. In some embodiments, the disambiguation message may indicate that the execution of the identifying/distinguishing task or maneuver is to be delayed until an execution message is received. The execution message may be a message from the observer's computing device indicating that the identifying/distinguishing task or maneuver should be executed. In this manner, the observer may state the action to perform and that the robotic vehicle/robotic vehicle operator should be prepared to receive a follow-up notification at a certain time or within a window of time at which the action is to be performed. For example, the disambiguation message may be a request that a LED should be flashed in response to the execution message. The observer's computing device may send the execution message as the next follow-up notification and the robotic vehicle operator may execute the identifying/distinguishing task or maneuver in response to receiving the execution message (e.g., flash the LED). The identification window may begin upon the receipt of the execution message or the execution message may indicate the identification window of time.

FIG. **7** illustrates a method **700** for verifying an identifying/distinguishing task or maneuver according to some embodiments. With reference to FIGS. **1-7**, the method **700** may be implemented in hardware components and/or software components of the robotic vehicle (e.g., **102**, **104**, **200**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle. In some embodiments, the operations of the method **700** may be performed in conjunction with the operations of the methods **300**, **350**, **500**, **600**, and/or **650**. In some embodiments, the operations of the method **700** may be performed subsequent to the operations of block **304** of the method **300**.

In determination block **702**, the processor may identify whether an identifying/distinguishing task or maneuver violates one or more vehicle constraints. Vehicle constraints may be limitations on the operations that a robotic vehicle may perform within structural, aerodynamic, safety, or other limits. For example, vehicle constraints may be associated with the design of the vehicle (e.g., the vehicle aerodynamics may not support certain maneuvers, the vehicle may lack lights, a maneuver would overstress the vehicle or some component, etc.). As another example, vehicle constraints may be associate with the mission of the robotic vehicle (e.g., the robotic vehicle may be a military vehicle that should not turn on its lights during a mission, the robotic vehicle may be carrying a heavy and/or delicate payload limiting its maneuverability, etc.) As a further example,

vehicle constraints may be associated with safety considerations (e.g., speed limits, maximum or minimum altitude restrictions, etc.)

In response to determining that the identifying/distinguishing task or maneuver does not violate one or more vehicle constraints (i.e., determination block **702**="No"), the processor of the robotic vehicle may perform operations of the method **300** in blocks **306** or **352-368** to execute the task.

In response to determining that the identifying/distinguishing task or maneuver violates one or more vehicle constraints (i.e., determination block **702**="Yes"), the processor of the robotic vehicle may block the execution of the identifying/distinguishing task or maneuver in block **704**. For example, the processor may ignore or drop the disambiguation message and/or the processor may not pass the identifying/distinguishing task or maneuver to an avionics module. In some embodiments, in response to blocking the identifying/distinguishing task or maneuver execution, the processor may send an indication of the constraint violation to the observer's computing device in block **706**. As examples, the indication may be a message indicating that the robotic vehicle is on a military mission, cannot perform a barrel roll, is prohibit from flying below or above an altitude restriction, etc.

FIG. **8**A illustrates a method **800** for disambiguating a robotic vehicle operator according to some embodiments. With reference to FIGS. **1-8**A, the method **800** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**), the robotic vehicle (e.g., **102**, **104**, **200**), and/or an operator's computing device (e.g., operator's computing device **118**, **124**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle, observer's computing device, and/or operator's computing device. In some embodiments, the operations of the method **800** may be performed in conjunction with the operations of the methods **300**, **350**, **500**, **600**, **650**, and/or **700**. In some embodiments, the operations of the method **800** may be performed subsequent to the operations of blocks **306** of the method **300**.

In block **802**, the robotic vehicle processor may forward the disambiguation message to the operator's computing device. In block **804**, the operator's computing device may receive the disambiguation message. In some embodiments, a disambiguation message may include an operator identifying task. An operator identifying task may be an indication of an action that an operator of a robotic vehicle should take to identify him or herself visually. For example, an operator identifying task may be an indication to an operator of a robotic vehicle to wave his or her arm in the air, turn around, or make some other type of motion/gesture.

In response to receiving the disambiguation message including an operator identifying task, the processor of the operator's computing device may display an indication of the operator identifying task in block **806**. As examples, the processor may control a display or speaker of the operator's computing device to output a message of "wave your arm above your head." The observer may look for an operator waving his or her arm above his or her head to differentiate the operator associated with the robotic vehicle receiving the disambiguation message from other operators and individuals.

FIG. **8**B illustrates a method **850** for disambiguating a robotic vehicle operator according to some embodiments. With reference to FIGS. **1-8**B, the method **850** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**), the robotic vehicle (e.g., **102**, **104**, **200**), and/or an operator's computing device (e.g., operator's computing device **118**, **124**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle, observer's computing device, and/or operator's computing device. In some embodiments, the operations of the method **800** may be performed in conjunction with the operations of the methods **300**, **350**, **500**, **600**, **650**, **700**, and/or **800**. In some embodiments, the operations of the method **850** may be performed subsequent to the operations of blocks **362** of the method **300**. In block **806**, the processor of the operator's computing device may perform like operation of like numbered block of the method **800**.

FIG. **9** illustrates an example of a robotic vehicle operator being identified according to an embodiment. With reference to FIGS. **1-9**, the operator identification may be performed according to operations of the methods **800** and/or **850**. For example, the disambiguation message from the observer's computing device **108** may result in the operator's computing device **118** displaying a message **902**, such as "Wave". The operator **116** may wave his or her arm as illustrated such that the observer **106** may determine that operator **116** is associated with robotic vehicle **102**, rather than operator **122** who may be controlling another robotic vehicle **104**.

FIG. **10** illustrates a method for disambiguating a robotic vehicle according to some embodiments. With reference to FIGS. **1-10**, the method **1000** may be implemented in hardware components and/or software components of an observer's computing device (e.g., observer's computing device **108**) and/or the robotic vehicle (e.g., **102**, **104**, **200**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle and/or operator's computing device (e.g., **118**, **124**).

In optional block **1002**, the observer's computing device processor may send an identifier request. An identifier request may be a message requesting a robotic vehicle receiving the message send an identifier of the robotic vehicle. In optional block **1004**, the robotic vehicle processor may receive the identifier request. For example, identifier request may be sent/received via the wireless communication path **110**, **112**. Blocks **1002** and **1004** may be optional because robotic vehicles may not need to be interrogated to send identifiers, and in some embodiments robotic vehicles may continually or periodically transmit their respective identifiers automatically.

In block **1006**, the robotic vehicle processor may send an identifier message. In some embodiments, a robotic vehicle may generate an identifier message indicating an identifying/distinguishing task or maneuver the robotic vehicle is going to execute within an identification window or is already executing. The identifier message may be periodically sent by the robotic vehicle or may be sent in response to the robotic vehicle receiving an identifier request. The identifier message may also include the identifier of the robotic vehicle. This identifier may be a unique ID to the robotic vehicle, such as a tail number, media access control (MAC) address, identification friend or foe (IFF) code, or other ID and may include or be associated with a SSL certificate, TLS certificate, or other cryptographic token. For example, identifier message may be sent via the wireless communication path **110**, **112**.

In block **1012**, the processor of the robotic vehicle may control one or more components to execute the identifying/distinguishing task or maneuver. Executing the identifying/

distinguishing task or maneuver may be performed in a similar manner as described with reference to block **306** of the method **300**.

In block **1008**, the observer's computing device processor may receive the identifier message. In block **1014**, the processor of the observer's computing device may display an indication of the identifying/distinguishing task or maneuver. In this manner, identifying/distinguishing task or maneuvers may be executed and indicated to observers without needing a disambiguation message to be sent by the observer.

FIG. **11** illustrates a method for robotic vehicle emergency condition signaling according to some embodiments. With reference to FIGS. **1-11**, the method **1100** may be implemented in hardware components and/or software components of a robotic vehicle (e.g., **102**, **104**, **200**), the operation of which may be controlled by one or more processors (e.g., the processor **220** and/or the like) of the robotic vehicle. In some embodiments, the operations of the method **1100** may be performed in conjunction with the operations of the methods **300**, **350**, **500**, **600**, **650**, **700**, **800**, **850**, and/or **1000**.

In block **1102**, the processor may monitor the radio status. For example, the processor of the robotic vehicle may determine whether the radio is functioning properly. In determination block **1104**, the processor may determine whether there is a radio outage. In response to determining that no radio outage exists (i.e., determination block **1104**="No"), the processor may continue to monitor the radio communication link in block **1102**.

In response to detecting a radio outage (i.e., determination block **1104**="Yes"), the processor may determine whether an emergency condition is occurring in determination block **1106**. Example, emergency conditions may include loss of GPS, motor failure, the radio outage itself, etc.). In response to determining that no emergency condition is occurring (i.e., determination block **1106**="No"), the processor may continue to monitor the radio link status in block **1102**.

In response to determining that an emergency condition is occurring (i.e., determination block **1106**="Yes"), the processor of the robotic vehicle may control one or more components to execute a condition identifying/distinguishing task or maneuver in block **1108**. The condition identifying/distinguishing task or maneuver may be a predetermined task or maneuver to indicate the radio outage and/or emergency condition to an observer. For example, when a radio outage has occurred and GPS is lost, the robotic vehicle may execute a predetermined identifying/distinguishing task or maneuver to flash a LED red once every three seconds. An observer or operator may see that flashing red LED at the three second interval and determine the robotic vehicle has experience a radio outage and GPS loss. The observer or operator may then take appropriate action for the indicated emergency condition even though the emergency condition could not be communicated via radio due to the radio outage. Executing the condition identifying/distinguishing task or maneuver may be performed in a similar manner as described with reference to block **306** of FIG. **3**A.

Various embodiments (including, but not limited to, embodiments discussed with reference to FIGS. **1-11**) may be implemented within a processing device **1210** configured to be used in a robotic vehicle (e.g., robotic vehicles **102**, **104**). As such, the processing device **1210** may implement the methods **300**, **350**, **500**, **600**, **650**, **700**, **800**, **850**, **1000**, **1100** in FIGS. **3**A, **3**B, **5**, **6**A, **6**B, **7**, **8**A, **8**B, **10**, and **11**. A processing device may be configured as or including a system-on-chip (SOC) **1212**, an example of which is illustrated FIG. **12**. With reference to FIGS. **1-12**, the SOC **1212** may include (but is not limited to) a processor **1214**, a memory **1216**, a communication interface **1218**, and a storage memory interface **1220**. The processing device **1210** or the SOC **1212** may further include a communication component **1222**, such as a wired or wireless modem, a storage memory **1224**, an antenna **1226** for establishing a wireless communication link, and/or the like. The processing device **1210** or the SOC **1212** may further include a hardware interface **1228** configured to enable the processor **1214** to communicate with and control various components of a robotic vehicle. The processor **1214** may include any of a variety of processing devices, for example any number of processor cores.

The term "system-on-chip" or SOC is used herein to refer to a set of interconnected electronic circuits typically, but not exclusively, including one or more processors (e.g., **1214**), a memory (e.g., **1216**), and a communication interface (e.g., **1218**). The SOC **1212** may include a variety of different types of processors **1214** and processor cores, such as a general purpose processor, a central processing unit (CPU), a digital signal processor (DSP), a graphics processing unit (GPU), an accelerated processing unit (APU), a subsystem processor of specific components of the processing device, such as an image processor for a camera subsystem or a display processor for a display, an auxiliary processor, a single-core processor, and a multicore processor. The SOC **1212** may further embody other hardware and hardware combinations, such as a field programmable gate array (FPGA), an application-specific integrated circuit (ASIC), other programmable logic device, discrete gate logic, transistor logic, performance monitoring hardware, watchdog hardware, and time references. Integrated circuits may be configured such that the components of the integrated circuit reside on a single piece of semiconductor material, such as silicon.

The SoC **1212** may include one or more processors **1214**. The processing device **1210** may include more than one SoC **1212**, thereby increasing the number of processors **1214** and processor cores. The processing device **1210** may also include processors **1214** that are not associated with an SoC **1212** (i.e., external to the SoC **1212**). Individual processors **1214** may be multicore processors. The processors **1214** may each be configured for specific purposes that may be the same as or different from other processors **1214** of the processing device **1210** or SOC **1212**. One or more of the processors **1214** and processor cores of the same or different configurations may be grouped together. A group of processors **1214** or processor cores may be referred to as a multi-processor cluster.

The memory **1216** of the SoC **1212** may be a volatile or non-volatile memory configured for storing data and processor-executable instructions for access by the processor **1214**. The processing device **1210** and/or SoC **1212** may include one or more memories **1216** configured for various purposes. One or more memories **1216** may include volatile memories such as random access memory (RAM) or main memory, or cache memory.

Some or all of the components of the processing device **1210** and the SOC **1212** may be arranged differently and/or combined while still serving the functions of the various aspects. The processing device **1210** and the SOC **1212** may not be limited to one of each of the components, and multiple instances of each component may be included in various configurations of the processing device **1210**

The various embodiments (including, but not limited to, embodiments discussed with reference to FIGS. **1-11**) may be implemented in a wide variety of computing devices include a laptop computer **1300** an example of which is illustrated in FIG. **13**. As such, the laptop computer **1300** may implement the methods **300**, **350**, **500**, **600**, **650**, **700**, **800**, **850**, **1000**, **1100** in FIGS. **3**A, **3**B, **5**, **6**A, **6**B, **7**, **8**A, **8**B, **10**, and **11**. Many laptop computers include a touchpad touch surface **1317** that serves as the computing device's pointing device, and thus may receive drag, scroll, and flick gestures similar to those implemented on computing devices equipped with a touch screen display and described above. A laptop computer **1300** will typically include a processor **1311** coupled to volatile memory **1312** and a large capacity nonvolatile memory, such as a disk drive **1313** of Flash memory.

The laptop computer **1300** may also include one or more hardware components **1330** coupled to the processor **1311** and configured to perform functions and operations of the various embodiments. Additionally, the laptop computer **1300** may have one or more antenna **1308** for sending and receiving electromagnetic radiation that may be connected to a wireless transceiver **1316** (e.g., a wireless data link transceiver (such as a Bluetooth®, Wi-Fi®, or any other type wireless data link transceiver, etc.), cellular network transceiver (such as a CDMA, TDMA, GSM, 3G, 4G, LTE, or any other type of cellular network transceiver), etc.) coupled to the processor **1311**. The laptop computer **1300** may also include a floppy disc drive **1314** and a compact disc (CD) drive **1315** coupled to the processor **1311**. In a notebook configuration, the computer housing includes the touchpad **1317**, the keyboard **1318**, and the display **1319** all coupled to the processor **1311**. Other configurations of the computing device may include a computer mouse or trackball coupled to the processor (e.g., via a Universal Serial Bus (USB) input) as are well known, which may also be used in conjunction with the various embodiments.

The various embodiments (including, but not limited to, embodiments discussed above with reference to FIGS. **1-11**) may be implemented in any of a variety of the computing devices including a mobile device **1400**, an example of which is illustrated in FIG. **14**. As such, the mobile device **1400** may implement the methods **300**, **350**, **500**, **600**, **650**, **700**, **800**, **850**, **1000**, **1100** in FIGS. **3**A, **3**B, **5**, **6**A, **6**B, **7**, **8**A, **8**B, **10**, and **11**. For example, the mobile device **1400** may include a processor **1401** coupled to a touch screen controller **1404** and an internal memory **1402**. The processor **1401** may be one or more multicore integrated circuits (ICs) designated for general or specific processing tasks. The internal memory **1402** may be volatile or non-volatile memory, and may also be secure and/or encrypted memory, or unsecure and/or unencrypted memory, or any combination thereof. The touch screen controller **1404** and the processor **1401** may also be coupled to a touch screen panel **1412**, such as a resistive-sensing touch screen, capacitive-sensing touch screen, infrared sensing touch screen, etc. The mobile device **1400** may have one or more radio signal transceivers **1408** (e.g., Peanut®, Bluetooth®, Zigbee®, Wi-Fi, RF, cellular, etc.) and antennae **1410**, for sending and receiving, coupled to each other and/or to the processor **1401**. The transceivers **1408** and antennae **1410** may be used with the above-mentioned circuitry to implement various wireless transmission protocol stacks and interfaces and to establish the various wireless links discussed herein. The mobile device **1400** may include one or more cellular network wireless modem chips **1416**, such as one cellular network wireless modem chip, two cellular network wireless modem chips, three cellular network wireless modem chips, four cellular network wireless modem chips, or more than four cellular network wireless modem chips, that enables communication via one or more cellular networks and that are coupled to the processor **1401**. The one or more cellular network wireless modem chips **1416** may enable the mobile device **1400** to receive services from one or more cellular networks (e.g., CDMA, TDMA, GSM, 3G, 4G, LTE, or any other type of cellular network), to implement various wireless transmission protocol stacks and interfaces, and to establish the various wireless links discussed herein.

The mobile device **1400** may include a peripheral device connection interface **1418** coupled to the processor **1401**. The peripheral device connection interface **1418** may be singularly configured to accept one type of connection, or multiply configured to accept various types of physical and communication connections, common or proprietary, such as USB, FireWire, Thunderbolt, Ethernet, or PCIe. The peripheral device connection interface **1418** may also be coupled to a similarly configured peripheral device connection port (not shown). The mobile device **1400** may also include speakers **1414** for providing audio outputs.

The mobile device **1400** may also include a housing **1420**, constructed of a plastic, metal, or a combination of materials, for containing all or some of the components discussed herein. The mobile device **1400** may include a power source **1422** coupled to the processor **1401**, such as a disposable or rechargeable battery. The rechargeable battery may also be coupled to the peripheral device connection port to receive a charging current from a source external to the mobile device **1400**.

The processors **220**, **1214**, **1311**, **1401** may be any programmable microprocessor, microcomputer or multiple processor chip or chips that can be configured by software instructions (applications) to perform a variety of functions, including the functions of the various embodiments described above. In some devices, multiple processors may be provided, such as one processor dedicated to wireless communication functions and one processor dedicated to running other applications. Typically, software applications may be stored in the internal memory before they are accessed and loaded into the processors **220**, **1214**, **1311**, **1401**. The processors **220**, **1214**, **1311**, **1401** may include internal memory sufficient to store the application software instructions. In many devices, the internal memory may be a volatile or nonvolatile memory, such as flash memory, or a mixture of both. For the purposes of this description, a general reference to memory refers to memory accessible by the processors **220**, **1214**, **1311**, **1401** including internal memory or removable memory plugged into the device and memory within the processors **220**, **1214**, **1311**, **1401** themselves.

Various embodiments illustrated and described are provided merely as examples to illustrate various features of the claims. However, features shown and described with respect to any given embodiment are not necessarily limited to the associated embodiment and may be used or combined with other embodiments that are shown and described. Further, the claims are not intended to be limited by any one example embodiment. For example, one or more of the operations of the methods **300**, **350**, **500**, **600**, **650**, **700**, **800**, **850**, **1000**, and **1100** may be substituted for or combined with one or more operations of the methods **300**, **350**, **500**, **600**, **650**, **700**, **800**, **850**, **1000**, and **1100**, and vice versa.

The foregoing method descriptions and the process flow diagrams are provided merely as illustrative examples and are not intended to require or imply that the steps of the

various embodiments must be performed in the order presented. As will be appreciated by one of skill in the art the order of steps in the foregoing embodiments may be performed in any order. Words such as "thereafter," "then," "next," etc. are not intended to limit the order of the steps; these words are simply used to guide the reader through the description of the methods. Further, any reference to claim elements in the singular, for example, using the articles "a," "an" or "the" is not to be construed as limiting the element to the singular.

The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the claims.

The hardware used to implement the various illustrative logics, logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Alternatively, some steps or methods may be performed by circuitry that is specific to a given function.

In various embodiments, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions or code on a non-transitory computer-readable medium or non-transitory processor-readable medium. The steps of a method or algorithm disclosed herein may be embodied in a processor-executable software module, which may reside on a non-transitory computer-readable or processor-readable storage medium. Non-transitory server-readable, computer-readable or processor-readable storage media may be any storage media that may be accessed by a computer or a processor. By way of example but not limitation, such non-transitory server-readable, computer-readable or processor-readable media may include RAM, ROM, EEPROM, FLASH memory, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of non-transitory server-readable, computer-readable and processor-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a non-transitory server-readable, processor-readable medium and/or computer-readable medium, which may be incorporated into a computer program product.

The preceding description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the claims. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the scope of the claims. Thus, the claims are not intended to be limited to the embodiments described herein but are to be accorded the widest scope consistent with the following claims and the principles and novel features disclosed herein.

What is claimed is:

1. A method of disambiguating a robotic vehicle, comprising:

receiving, in a processor of the robotic vehicle, a disambiguation message from an observer's computing device while the robotic vehicle is operating at least in part under control of an operator's computing device that is different from the operator's computing device; and

controlling, by the processor of the robotic vehicle, one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to receiving the disambiguation message.

2. The method of claim **1**, wherein controlling one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver is performed within an identification window of time indicated in the disambiguation message.

3. The method of claim **1**, further comprising:

forwarding the disambiguation message from the processor of the robotic vehicle to the operator's computing device; and

receiving, in the processor of the robotic vehicle, an instruction to execute the identifying/distinguishing task or maneuver from the operator's computing device,

wherein controlling, by the processor of the robotic vehicle, one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver is performed in response to the instruction to execute the identifying/distinguishing task or maneuver received from the operator's computing device.

4. The method of claim **3**, wherein the disambiguation message includes an operator identifying task comprising at least one of a gesture or motion of an operator to be performed.

5. The method of claim **1**, further comprising receiving an execution message prior to executing the identifying/distinguishing task or maneuver.

6. The method of claim **1**, further comprising:

determining, by the processor of the robotic vehicle, whether an identifying/distinguishing task or maneuver indicated in the disambiguation message violates one or more vehicle constraints; and

blocking execution of the identifying/distinguishing task or maneuver indicated in the disambiguation message by the processor of the robotic vehicle in response to determining that the identifying/distinguishing task or

maneuver indicated in the disambiguation message violates one or more vehicle constraints.

7. The method of claim 1, wherein the identifying/distinguishing task or maneuver is one or more of performing a maneuver, controlling a visual indicator, and generating an audible indicator.

8. The method claim 1, wherein:

the disambiguation message includes an indication of data for the robotic vehicle to provide the observer's computing device; and

the identifying/distinguishing task or maneuver comprises sending the data for the robotic vehicle from the processor of the robotic vehicle to the observer's computing device.

9. The method of claim 8, wherein the data for the robotic vehicle includes one or more of an image file of the robotic vehicle or a modem serial number of the robotic vehicle.

10. The method of claim 1, further comprising:

determining, by the processor of the robotic vehicle, whether an emergency condition of the robotic vehicle is occurring; and

controlling, by the processor of the robotic vehicle, one or more components of the robotic vehicle to execute a second identifying/distinguishing task or maneuver in response to determining that the emergency condition of the robotic vehicle is occurring.

11. A robotic vehicle, comprising:

a processor configured with processor-executable instructions to:

receive a disambiguation message from an observer's computing device while the robotic vehicle is operating at least in part under control of an operator's computing device that is different from the operator's computing device;

control one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to receiving the disambiguation message.

12. The robotic vehicle of claim 11, wherein the processor is further configured with processor-executable instructions to control one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver within an identification window of time indicated in the disambiguation message.

13. The robotic vehicle of claim 12, wherein the processor is further configured with processor-executable instructions to:

determine whether an emergency condition of the robotic vehicle is occurring; and

control one or more components of the robotic vehicle to execute a second identifying/distinguishing task or maneuver in response to determining that the emergency condition of the robotic vehicle is occurring.

14. The robotic vehicle of claim 11, wherein:

the processor is further configured with processor-executable instructions to:

forward the disambiguation message to the operator's computing device; and

receive an instruction to execute the identifying/distinguishing task or maneuver from the operator's computing device; and

the processor is further configured with processor-executable instructions to control one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to the instruction to execute the identifying/distinguishing task or maneuver received from the operator's computing device.

15. The robotic vehicle of claim 14, wherein the disambiguation message includes an operator identifying task comprising a gesture or motion of an operator to be performed.

16. The robotic vehicle of claim 11, wherein the processor is further configured with processor-executable instructions to receive an execution message prior to executing the identifying/distinguishing task or maneuver.

17. The robotic vehicle of claim 11, wherein the processor is further configured with processor-executable instructions to:

determine whether an identifying/distinguishing task or maneuver indicated in the disambiguation message violates one or more vehicle constraints; and

block execution of the identifying/distinguishing task or maneuver indicated in the disambiguation message in response to determining that the identifying/distinguishing task or maneuver indicated in the disambiguation message violates one or more vehicle constraints.

18. The robotic vehicle of claim 11, wherein the processor is further configured with processor-executable instructions such that the identifying/distinguishing task or maneuver is one or more of performing a maneuver, controlling a visual indicator, and generating an audible indicator.

19. The robotic vehicle of claim 11, wherein the processor is further configured with processor-executable instructions such that:

the disambiguation message includes an indication of data for the robotic vehicle to provide the observer's computing device; and

the identifying/distinguishing task or maneuver comprises sending the data for the robotic vehicle from the processor of the robotic vehicle to the observer's computing device.

20. The robotic vehicle of claim 19, wherein the processor is further configured with processor-executable instructions such that the data for the robotic vehicle is one or both of an image file of the robotic vehicle or a modem serial number of the robotic vehicle.

21. A robotic vehicle, comprising:

means for receiving a disambiguation message from an observer's computing device while the robotic vehicle is operating at least in part under control of an operator's computing device that is different from the operator's computing device; and

means for controlling one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to receiving the disambiguation message.

22. The robotic vehicle of claim 21, wherein means for controlling one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver comprises means for controlling one or more components of the robotic vehicle to execute the identifying/distinguishing task or maneuver within an identification window of time indicated in the disambiguation message.

23. The robotic vehicle of claim 21, further comprising:

means for forwarding the disambiguation message from the processor of the robotic vehicle to the operator's computing device; and

means for receiving an instruction to execute the identifying/distinguishing task or maneuver from the operator's computing device,

wherein means for controlling one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver means for controlling one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to the instruction to execute the identifying/distinguishing task or maneuver received from the operator's computing device.

24. The robotic vehicle of claim **21**, further comprising means for receiving an execution message prior to executing the identifying/distinguishing task or maneuver.

25. The robotic vehicle of claim **21**, further comprising:

means for determining whether an identifying/distinguishing task or maneuver indicated in the disambiguation message violates one or more vehicle constraints; and

means for blocking execution of the identifying/distinguishing task or maneuver indicated in the disambiguation message in response to determining that the identifying/distinguishing task or maneuver indicated in the disambiguation message violates one or more vehicle constraints.

26. The robotic vehicle claim **21**, wherein:

the disambiguation message includes an indication of data for the robotic vehicle to provide the observer's computing device; and

the identifying/distinguishing task or maneuver comprises sending the data for the robotic vehicle from the processor of the robotic vehicle to the observer's computing device.

27. The robotic vehicle of claim **21**, further comprising:

means for determining whether an emergency condition of the robotic vehicle is occurring; and

means for controlling one or more components of the robotic vehicle to execute a second identifying/distinguishing task or maneuver in response to determining that the emergency condition of the robotic vehicle is occurring.

28. A processing device configured for use in a robotic vehicle and configured to:

receive a disambiguation message from an observer's computing device while the robotic vehicle is operating at least in part under control of an operator's computing device that is different from the operator's computing device; and

control the processor of the robotic vehicle, one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to receiving the disambiguation message.

29. The processing device of claim **28**, wherein the processor device is further configured to:

forward the disambiguation message to the operator's computing device; and

receive an instruction to execute the identifying/distinguishing task or maneuver from the operator's computing device; and

the processor device is further configured to control one or more components of the robotic vehicle to execute an identifying/distinguishing task or maneuver in response to the instruction to execute the identifying/distinguishing task or maneuver received from the operator's computing device.

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